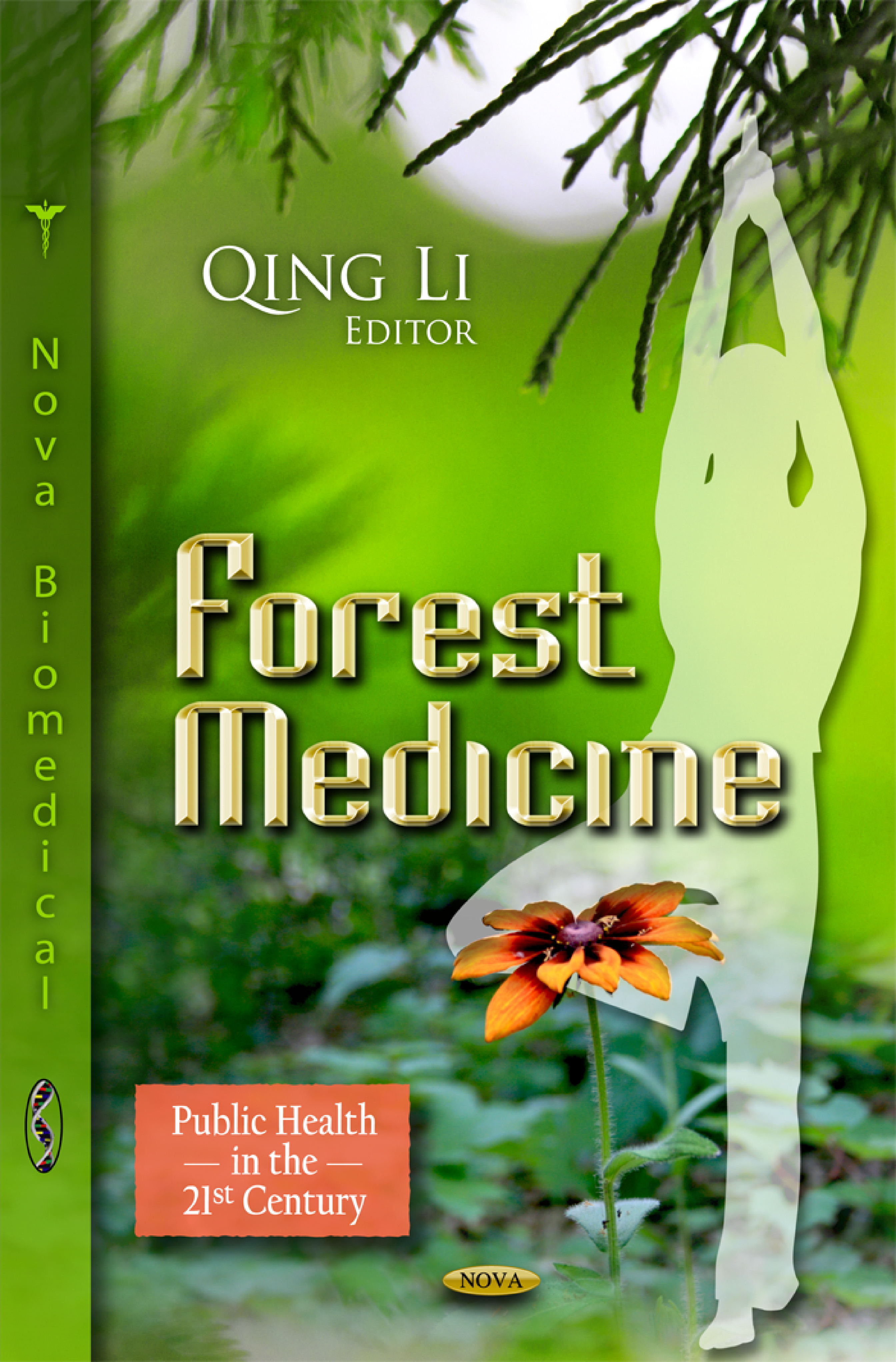
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PUBLIC HEALTH IN THE 21ST CENTURY

FOREST MEDICINE

QING LI
EDITOR

New York

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Contents

Preface

Imagine a new medical science that could let you know how to be more active, more relaxed and healthier with reduced stress and reduced risk of lifestyle-related disease and cancer by visiting forests. This new medical science is Forest Medicine. The Forest Medicine encompasses the effects of forest environments on human health and is a new interdisciplinary science, belonging to the categories of alternative medicine, environmental medicine and preventive medicine. The term Forest Medicine in Japanese (Shinrin Igaku) was first proposed in 2006. The term was first used in English when the Japanese Society of Forest Medicine was established in 2007.

Evidence-based research on forest environments and human health (Forest Medicine) began in earnest in 2004 when the Japanese Society of Forest Therapy was established. The Ministry of Agriculture, Forestry and Fisheries of Japan also initiated a research project between 2004 and 2006 to investigate the therapeutic effects of forests on human health from a scientific perspective. The project has yielded a vast amount of data on the effects of forest environments, proving that forests promote both physical and mental health by reducing stress.

The goal of this book is to present up-to-date findings in Forest Medicine to show the beneficial effects of forest environments on human health. The book has 22 chapters organized into six sections as follows:

Section 1 Introduction
Section 2 Evaluation of the forest environment
Section 3 Effects of the forest environment on human health
Section 4 Effects of factors in the forest environments on human health
Section 5 Green areas and human health: epidemiological studies
Section 6 Research into forests and human health - recent trends worldwide

The book includes evidence from both experimental and epidemiological studies, and covers recent trends on the forests and human health in Japan, Korea, China and Europe.

The book should appeal to a broad audience in the fields of forestry, horticulture, alternative medicine, environmental medicine, preventive medicine/public health, and aromatherapy.

As an editor, I would like to thank all the authors for the time and effort they devoted to each chapter and hope that this novel work will aid the understanding of forests and human health.

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Section 1. Introduction

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Chapter 1

What is Forest Medicine?

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Background

In Japan, rates of cancer and lifestyle-related diseases such as heart disease, diabetes, cerebrovascular disease and hypertension are increasing. According to the Ministry of Health, Labour and Welfare of Japan [1], the percentage of workers with anxiety and stress was more than 50% in 1982, 62.8% in 1997, and 58% in 2007 (Figure 1), suggesting a major mental health problem. Recently, metabolic syndrome has become a focus of public attention [2].

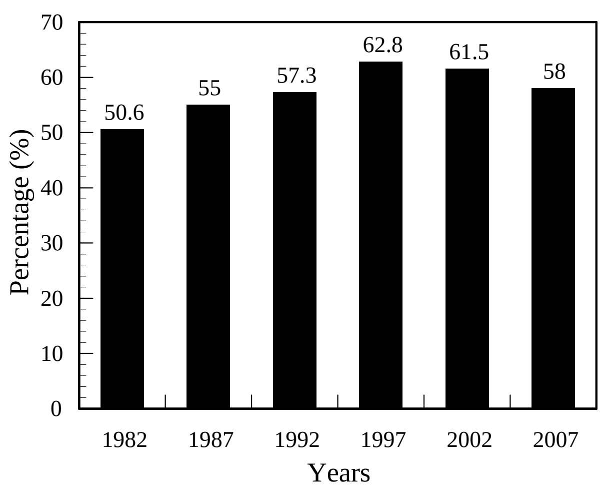

Figure 1. Rates of anxiety and stress among workers in Japan during 1982-2007 reported by the Ministry of Health, Labour and Welfare.

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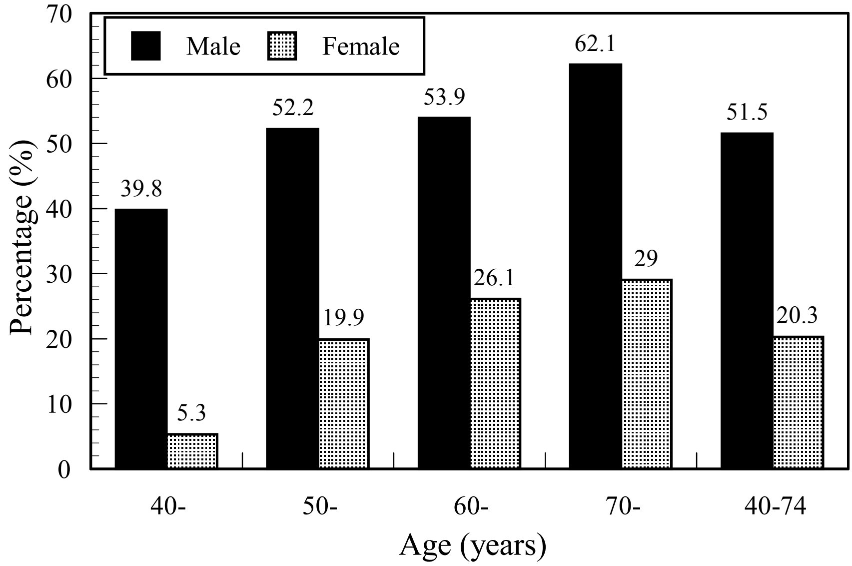

Figure 2. People at 40-74 years old with metabolic syndrome or in the pre-stage of metabolic syndrome in 2006 in Japan reported by the Ministry of Health, Labour and Welfare.

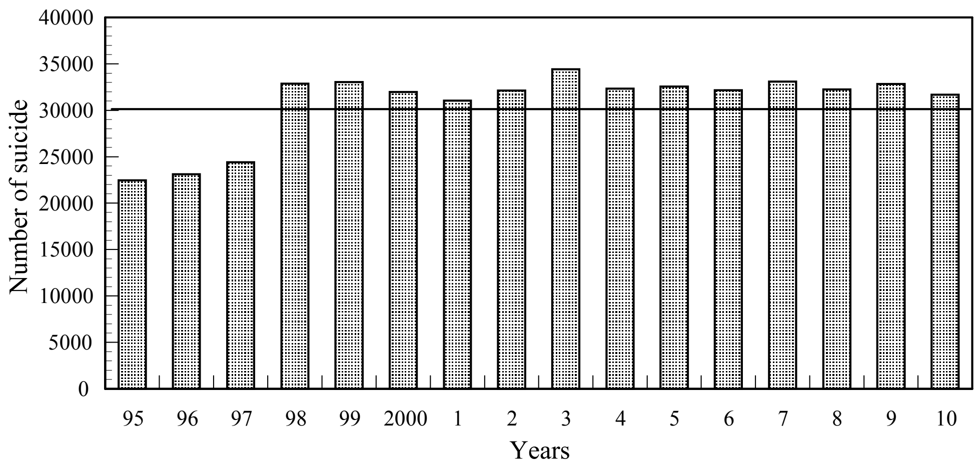

Figure 3. Trends of suicide in Japan during 1995-2010 reported by the National Police Agency.

The Ministry of Health, Labour and Welfare of Japan calculated that metabolic syndrome or pre-stage metabolic syndrome affected approximately 20 million Japanese in 2006, including about 50 % of middle-aged males and 20 % of middle-aged females 40-74 years old (Figure 2) [3]. Moreover, according to the National Police Agency of Japan [4], more than 30,000 people have committed suicide every year since 1998 (Figure 3); in 2007, there were 33,093 reported suicides, 14,684 of which were due to health problems including 6,060 due to depression. Therefore, the health management of workers, especially in relation to stress-related diseases, has become a major social issue and an effective new method for prevention of diseases is needed. The forest environment has long been enjoyed for its quiet atmosphere, beautiful scenery, calm climate, and clean fresh air. Forest settings may reduce stress and have a relaxing effect; therefore, walking in forest parks or "Shinrin-yoku", literally “forest bathing” in Japanese, is increasing in popularity in Japan [5].

What Is a Forest?

In 2000, the Forest Resources Assessment (FRA) 2000 project defined the “forest” as follows (http://www.fao.org/DOCREP/004/Y1997E/y1997e1m.htm):

Forest includes natural forests and forest plantations. It is used to refer to land with a tree canopy cover of more than 10 percent and area of more than 0.5 ha. Forests are determined both by the presence of trees and the absence of other predominant land uses. The trees should be able to reach a minimum height of 5 m. Young stands that have not yet but are expected to reach a crown density of 10 percent and tree height of 5 m are included under forest, as are temporarily unstocked areas. The term includes forests used for purposes of production, protection, multiple-use or conservation (i.e. forest in national parks, nature reserves and other protected areas), as well as forest stands on agricultural lands (e.g. windbreaks and shelterbelts of trees with a width of more than 20 m), and rubberwood plantations and cork oak stands.

In Japan, forest is used to refer to land with a tree canopy cover of more than 30 percent and area of more than 0.3 ha. The trees should be able to reach a minimum height of 5 m with a width of more than 20 m (http://www.env.go.jp/earth/ondanka/santei_k/18_02/mat02_1.pdf). The forests include Japanese cypress *(Chamaecyparis obtuse*, Hinoki in Japanese), Japanese cedar (*Cryptomeria*, Sugi in Japanese), Japanese beech, Japanese oak, Japanese white birch, and so forth.

What Is a Forest Bathing Trip?

In Japan, a forest bathing trip is a short leisurely visit to a forest field, called “Shinrin-yoku” in Japanese, which is similar in effect to natural aromatherapy, for the purpose of relaxation and the breathing in of volatile substances called phytoncides (wood essential oils) derived from plants (trees), such as alpha-pinene and limonene. “Shinrin" means forest and "yoku” means bathing in Japanese. Incorporating forest bathing trips into a healthy lifestyle was first proposed in 1982 by the Forest Agency of Japan, and the first meeting was held at Akasawa in Nagano prefecture, northwestern Japan [5]. Because forests occupy 67% of the land in Japan, forest bathing is easily accessible [6]. It has become a recognized relaxation and/or stress management activity in Japan. Forest bathing as a method of preventing diseases and promoting health is becoming a focus of public attention.

How to Enjoy Forest Bathing?

People can enjoy the forest through all five senses: the fragrance of the forest, green colours of the plants, the murmuring of streams and singing of birds, the eating of forest foods and the touching of trees. Ten tips for forest bathing have been proposed by the author as follows [7]:

1. Make a plan based on your own physical abilities and avoid tiring yourself out.
2. If you have an entire day, stay in the forest for about 4 hours and walk about 5 kilometres. If you have just a half day, stay in the forest for about 2 hours and walk about 2.5 kilometres.
3. Take a rest whenever you have tired.
4. Drink water/tea whenever you feel thirsty.
5. Find a place you like, then sit for a while and read or enjoy the scenery.
6. If possible, bathe in a hot spring after the forest trip.
7. Select the forest bathing course based on your aims.
8. If you want to boost your immunity (natural killer activity), a three-day/two-night trip is recommended.
9. If you just want to relax and relieve stress, a day trip to a forested park near your home would be recommended.
10. Forest bathing is a preventive measure, so if you come down with an illness, see a doctor.

Evidence of Effects on Human Health

There has not been sufficient medical evidence supporting the therapeutic effects of forest bathing trips due to technical limitations regarding measurements, and evidence-based evaluations as well as a therapeutic menu of forest bathing have been requested. Against this background, the Ministry of Agriculture, Forestry and Fisheries of Japan initiated a research project between 2004 and 2006 to investigate the therapeutic effects of forests on human health from a scientific perspective. In addition, recent technological developments have enabled us to determine the effects of forest environments on human health. After several years, the project has obtained a vast amount of data, proving that forest bathing trips promote both physical and mental health by reducing stress [8-15].

The project has found that forest bathing trips reduce sympathetic nervous activity, increase parasympathetic nervous activity, and stabilize autonomic nervous activity by reducing levels of stress hormones such as cortisol in saliva [8-10] and urinary adrenaline and noradrenaline [11-13].

Forest bathing also reduces prefrontal cerebral activity [9], lowers blood pressure [8, 14] and has a relaxing effect [8-14]. Moreover, they found that visiting a forest, but not a city, increases human natural killer (NK) activity and the expression of anti-cancer proteins including perforin, granzymes A/B and granulysin [11-13, 15], and that the increased NK activity and anti-cancer proteins lasted for more than 7 days, even 30 days after the trip [11-13]. This suggests that if people take a forest bathing trip once a month, they may be able to maintain a higher level of NK activity. This is very important in terms of health promotion and preventive medicine.

What is Forest Medicine?

"Forest Medicine" has emerged as a new interdisciplinary science and a focus of public attention. Forest Medicine belongs to the categories of alternative medicine, environmental medicine and preventive medicine and is the study of the effects of forest environments on human health. The forest environment includes the following factors:

1. Physical factors: air temperature, humidity, illuminance, radiant heat, air current (wind velocity), sounds (the sound of a waterfall, the whispering of the wind in the trees), and so on (Chapter 2).
2. Chemical factors: volatile organic compounds derived from plants (trees), such as alpha-pinene and limonene, which are terpenes including hemiterpenes, monoterpenes, sesquiterpenes, and diterpenes, also called phytoncides [16, 17] (Chapter 3).
3. Psychological factors: those factors reflecting the subjective evaluation of forest environments such as hot/cold, light/dark, tense/relaxed, beautiful/ugly, good/bad, relaxing/stimulating, quiet/noisy, and plain/colorful. Semantic Differential (SD) is usually used to evaluate the psychological responses to forest environments. The technique was originally developed to measure affective responses to stimulus words and concepts in terms of ratings of bipolar scales defined with adjectives on each end [18]. The SD methodology is considered a simple, economical means of obtaining data on emotional reactions that could be used in many different situations or cultural contexts (Chapter 4).

The effect of forest environments on human health should be investigated from the following two perspectives:

1. Data/evidence obtained from experimental studies including field investigations and laboratory experiments, .i.e., investigations on the effect of walking in forests and natural environments on psycho-neuro-endocrino-immunology. These experiments study the effect of forest environments on the central nervous system (prefrontal cerebral activity, functional MRI), the sympathetic and parasympathetic nervous systems (blood pressure, heart rate variability), psychological responses (the POMS test), the endocrine system (stress hormones such as cortisol and adrenaline), and the immune system (NK activity, intracellular anti-cancer proteins in NK cells) determined by physiological, biological, biochemical, psychological, and immunological methods [8-13]. Recent technological developments have enabled us to conduct the above investigations in a forest field (Chapters 5-14).
2. Data/evidence obtained from epidemiological studies, i.e., investigations on the effect of exposure to forests and natural environments (green space) on the morbidity and mortality rates of diseases [6, 19, 20] (Chapters 15 -17).

Although Forest Medicine should include the health benefits that forests provide and risks that forests may pose, in the present book, we will only focus on the beneficial effects and do not discuss risks including forest-related infectious diseases, such as Puumala virus, Lyme borreliosis, Hantavirus cardiopulmonary syndrome, and malaria, and tick-borne encephalitis as well as dangerous wildlife, toxic fruits, foliage, and fungi.

With an increase in the evidence regarding the beneficial effects of forests on human health, many international research organizations/academic societies have launched projects to examine the relationship between forests and human health. In 2007, the Japanese Society of Forest Medicine, an academic society, was established [7]. The term Forest Medicine in English was first proposed in 2007 in Japan. The purpose of the Japanese Society of Forest Medicine is to promote research on Forest Medicine including the effects of forest bathing trips and therapeutic effects of forests on human health. The Society will collaborate with the Forest Agency of Japan, Forestry and Forest Products Research Institute of Japan, the Japanese Society of Forest Therapy, and other related academic societies to carry out the study in Forest Medicine, collecting and editing documents on the topic of forests and human health, and educational training on the practice of forest bathing trips. It is also to provide a platform for enterprises, universities and local governments who are interested in the practice of Forest Medicine for promoting the effective use of forest resources for stress management, health promotion, disease prevention and rehabilitation. In 2007, the International Union of Forest Research Organizations (IUFRO), which is the largest global collaboration on forest research, started a task force called Forests and Human Health [21]. The Task Force has two main objectives: 1) to support dialogue and information exchange between the various players in this field (scientists from different disciplines, policy-makers, implementing agencies and other stakeholders), especially between forest and health professionals; 2) to enhance the transfer of knowledge on the health benefits and risks of forests into practice. In Europe, the European Commission-funded Co-Operation in the Field of Science and Technical Research (COST) Action program, which is an intergovernmental network for coordination at the European level of research, was initiated by COST Action E39 in 2004. The main objective of the Action is to increase knowledge about the contribution that forests, trees and natural places make, and might make, to the health and well-being of people in Europe [22]. 2011 is the international year of the forest. The International Society of Nature and Forest Medicine (INFOM) was established in 2011 [23]. The purpose of the INFOM is to promote research on nature and forest medicine including the effects of forests and natural environments on global vision around the world. The INFOM will collaborate with the IUFRO, and other related academic societies to carry out the study of forest and nature medicine, and the collection and editing of documents on the topic of forests and human health. It is also to provide a platform for enterprises, universities and governments who are interested in the practice of nature and forest medicine for promoting the effective uses of forest resources for stress management, health promotion and the prevention and cure of diseases.

With the strong support of international forces, Forest Medicine will continue to develop and progress.

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Section 2. Evaluations of the Forest Environment

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Chapter 2

Physical Factors in the Forest Environment

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Abstract

It is said that the healing effects of forests are produced by gaining information about the physical environment of forests through our five senses. The effects of forest therapy are produced when we feel positively every environmental factor, such as the trees, flowers, and the activities of birds and insects, through our senses and sensory organs, while we carry out activities like walking there.

Therefore, it is very important to keep these healing effects and to understand information about the physical environments of forests where such forest therapy takes place. For these reasons, the spring – autumn period (May - October) in recent years, has seen the targeting of maintained walking trails through forests including at the northern and southern tips of Japan.

The research group authors participated in measured physical environmental activities during the day, in 30 forest sites chosen from forest environment sites around Japan. Especially focusing on the effects on the senses, organizing the results of measurements, and choosing important indicators from the factors composing the environment including the light, thermals, and sounds of the forest, we then compared those factors to the city environments we live in. Below are the results gained from this comparison;

1. Light environment: From the measurement of relative illuminance, the brightness of the forest environment was understood to be suitable for mild walks; however, the absolute illuminance of the forest environment was relatively lower in value and smaller in variability than that of the city.

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2. Thermal environment: Because transpiration and the emission is performed consistently from the tree leaves and soil in the forest, the air temperature, radiant heat and wind velocity were lower than in the city environment. However, the relative humidity in the forest was higher than that of the city.
3. Sound environment: The forest environment can have approximately the same sound pressure levels as the city environment from the chirping of cicada in the summer, however, in the forest environment, it became clear that the volume of sound may not necessarily lead to uncomfortable levels.

Keywords: Absolute and Relative illuminance, Air temperature, Relative humidity, Mean radiant heat, Sound pressure.

Introduction

Forest therapy produces an effect on people who conduct activities such as walking in the forest, and who feel every environmental factor in the forest (the forest environment) such as the flowers, trees, and the activities of birds and insects, through their senses and sensory organs. Therefore, it's very important to know information about the physical environment in the forest to maintain the effect of forest therapy. In particular, for a focus on its effect on the senses, in this paper we introduce measured results about the physical characteristics of the environmental factors of the forest environment by selecting certain indicators.

In Japan, many people visit forests to see fresh greenery in the springtime, and red leaves in the autumn. And the weather in summer months becomes very hot and humid, so people who live in the city tend to visit the cool of the forests. Thus, we can say that the time from spring to autumn is the most popular season for the recreational use of national forests. During this spring to autumn period every year (May to October), targeting maintained walking trails through the forest, the research group authors participated in measuring the physical environmental factors in 30 forest sites chosen from forest environment sites around Japan, during the daytime (09:00 to 16:00; Table 1). We also measured the same environmental factors at the same hours for comparison in 13 city environment sites near these forest sites (Table 1). We selected environmental factors related to four of the five senses (sight, hearing, smell, and touch) as measurement indicators for each of the senses.

The forest environment is composed of many factors, and it contains environmental factors which have an influence on people. But when people conduct research in the field, they have to consider such restrictions as the supply of electric power, the weight of equipment, and the convenience of equipment, so they select and measure environmental factors by considering a representation and simplified model of research.

Here, we will introduce the results of our scientific measurement of environmental factors related to vision or the "light environment (absolute illuminance, relative illuminance)", environmental factors related to touch or the "thermal environment (temperature, relative humidity, mean radiant heat, and wind velocity)", and environmental factors related to hearing or "sound environment (sound pressure)". These measurements were taken in the various study areas.

Table.1 Overview of study area

Year	2005									
Date	5/10	5/17	5/20	5/25,26	6/14	7/7,8	7/12,13	7/15	7/20	7/21
Site	B-pref. a'-town	A-pref. a-town	I-pref. b'-vil.	B-pref. B-town	J-pref. c'-city	C-pref. c-town	C-pref. d-city	K-pref. d'-city	K-pref. e'-city	L-pref. f'-vil.
Forest	○	○	○	○	○	○	○	○	○	○
City	×	○	×	○	×	○	○	×	×	×
Weather	fine	fine-cloudy	fine	fine/fine-cloudy	fine	cloudy/cloudy	cloudy/cloudy	fine	cloudy	fine
Year	2005									
Date	7/28	8/10,11	8/13	8/23	8/26	8/26	8/30,31	9/14,15	9/21	9/27,28
Site	D-pref. e-town	C-pref. f-town	C-pref. g'-vil.	C-pref. h'-vil.	M-pref. i'-town	M-pref. j'-vil.	C-pref. g-city	C-pref. h-vil.	N-pref. k'-town	E-pref. i-town
Forest	○	○	○	○	○	○	○	○	○	○
City	○	○	×	×	×	×	○	○	×	○
Weather	fine	cloudy-fine/cloudy	cloudy	cloudy	cloudy-fine	cloudy	fine-cloudy/fine	cloudy/fine-cloudy	fine-cloudy	fine-cloudy/cloudy
Year	2005							2006		
Date	9/30	10/4,5	10/25	10/31	11/10	11/17	2/14	8/2,3	8/10,11	9/6,8
Site	E-pref. l'-town	F pref. j-town	O-pref. m'-town	P-pref. n'-town	Q-pref. o'-town	Q-pref. p'-city	R-pref. q'-vil.	G-pref. k-town	H-pref. l-city	C-pref. m-vil.
Forest	○	○	○	○	○	○	○	○	○	○
City	×	○	×	×	×	×	×	○	○	○
Weather	rainy	rainy/fine	fine	fine	cloudy-fine	cloudy-fine	fine-cloudy	cloudy-fine/fine	fine/cloudy	cloudy-rainy/fine

The Light Environment of Forests

In terms of the light environment, it has be shown from the viewpoint of ecosystem management and silviculture in the forest, to be useful to measure using illumination and brightness (Koyama 1993), and illumination in particular is the most useful when examining the light environment. The comparison of broad-leaved and coniferous forests showed that broad-leaved forests were reported to be subjectively brighter than coniferous forests, even if the coniferous trees are actually brighter (Fujisawa et al. 2006). Research has also been carried out for studies that examined the 1/f fluctuation characteristics of illumination in different types of forests to examine the property of illumination that brings about the light environment (Fujisawa et al. 2008). In this way, it is considered to be one of the most important factors that the light environment resulting from sunshine filtering through foliage brings a sense of comfort in the forest. Therefore, it seems that understanding the light environment in the forest would be very important in terms of thinking about the meaning of comfort for forest therapy; however, in fact, what are the characteristics of illuminance in forest environments when compared with city environments? Our measurement methods and results are shown below.

Materials and Methods

- Measurements: Absolute illuminance (lux), relative illuminance (%)
- Equipment used: digital light meter (absolute illuminance: T-1H, Minolta, Figure 1), digital camera (relative illuminance: Coolpix4500, Nikon), fisheye lens (relative illuminance: FC-E8, Nikon, Figure 2)
- Measurement method: We walked the walking trails through the city and walking trails through the forest between the hours of 12:00 and 13:00, and measured at a frequency of once every 30 seconds. The relative light illuminance was measured only in the forest environment (Figure 3). We took pictures of 20 points of the sky above including at the start and the end using a digital camera equipped with a fisheye lens for relative illuminance measurements. Afterwards, we calculated relative illuminance using special software (Gap Light Analyzer made by Simon Fraser University).

Figure 1. Measurement of absolute illuminance.

Figure 2. Measurement of relative illuminance.

Figure 3. Example of Hemispherical Photograph.

Figure 4. Measurement of air temperature / relative humidity / wind velocity / radiant heat.

Results and Discussion

First, the relative illuminance (a number that indicates how much illuminance can be obtained relatively on open ground with no unobstructions) of the forest environment was measured (Figure 5). According to our report, on walking trails through forests that are maintained such as by pruning and mowing, the relative illuminance on average of the whole study area was approximately 29.0%, and the standard deviation was approximately ±9.0%. This means that the relative illuminance was reasonably bright for walking.

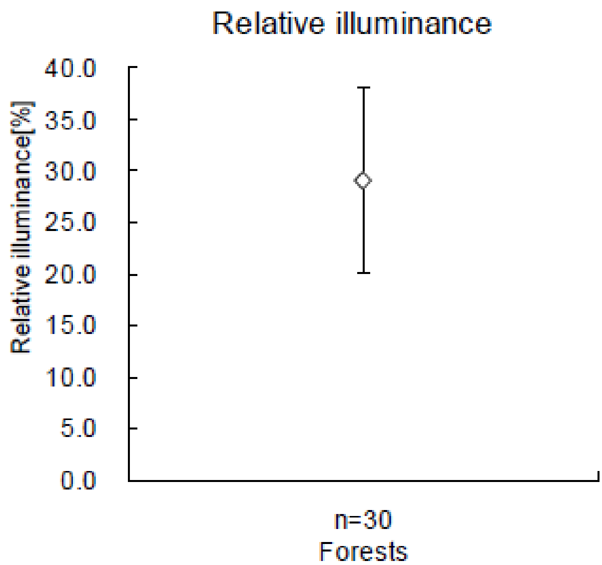

Figure 5. Relative illuminance (Mean±SD) Forests (29.0±9.0 %).

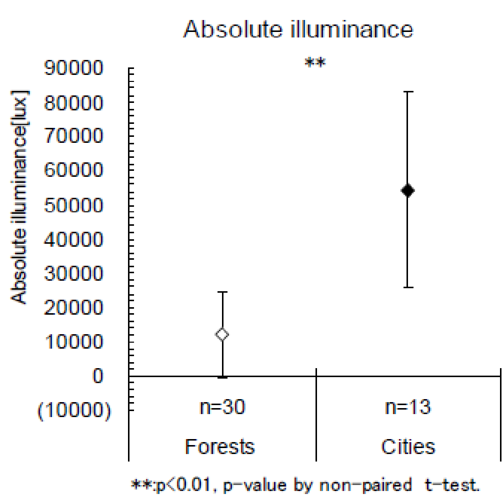

Figure 6. Absolute illuminance (Mean±SD), Forests (12,097±12,656 lux), Cities (54,301±28,508 lux).

The result of the measurement of about 30 places in forest environments (n = 30) and 13 places in city environments (n=13) were then organized (Figure 6). According to our report, the average illuminance for forest therapy was approximately 1.2×10^4 lux, whereas the average illumination on walking trails through the city was approximately 5.4×10^4 lux. To put this simply, the amount of illuminance in the forest environment in preparation for a walk, was 2/9 of the illuminance of in the city environment. Depending on the structure and density of tree species and the degree of care in the forest, the standard deviation of absolute illuminance for walking trails was approximately $\pm 1.27\times10^4$ whereas in the city environment it was approximately $\pm 2.85\times10^4$. These figure show that the figure of standard deviation for absolute illuminance in the forest environment is half that of the city environment.

As a result, the forest environment is reasonably bright for walking, and the figure of absolute illuminance for forest walking trails is smaller than that for city walking trails, with changes in illuminance within a small range meaning the light environment in the forest is less likely to cause glare and eye discomfort.

The Thermal Environment in the Forest

The thermal environment is the environment concerned with cutaneous sensations. It is often said that a forest environment has a higher mild weather function (Ishikawa 1985), and that many people visit forests in order to avoid heat in the summer, and for recreational purposes. At the same time, the measurement of physical weather factors such as air temperature, relative humidity, and wind velocity have been performed, but this has often been measured not for the purpose of studying the forest environment as a comfortable thermal environment, but for monitoring the growth environments of a plants and animals.

Therefore, in forest environments that are used by humans, there is little knowledge regarding the measurements of the thermal environment. In other words, understanding the forest environment as a place for performing forest bathing and walking, and other recreational activities, and comparisons with the city environment in terms of these activities, provides an opportunity to think about the thermal environment of the forest environment (Oishi 1994).

Materials and Methods

- Measurement items: air temperature (°C), relative humidity (%), mean radiant heat (°C), wind velocity (m / s).
- Equipment used: amenities meter (AM-101, Kyoto Electronic Industries, Figure 4)
- Measurement method: Select representative locations with walking trails through the forest and through the city, and measure automatically once every 10 minutes.

Results and Discussion

It's considered that certain climate factors relate to the thermal environment in the forest, so it's desirable to evaluate these key measures from various perspectives. Therefore, the four indicators of the thermal environment, air temperature (℃), relative humidity (%), mean radiant heat (℃), and wind velocity (m / s) were calculated, and organized as Figure 7, Figure 8, Figure 9, and Figure 10. First, in Figure 7, the air temperature in the forest environment was approximately 20.1℃ (standard deviation (S.D.): about ±4.8℃), whereas that in the city environment is about 26.0 ℃ (S.D.: about ±3.7℃). The air temperatures in the forest environment were 6 ℃ lower, and it can be said comfortable.

In addition, Figure 8 shows that the figures of relative humidity in the forest environment are 75.1% (S.D.: about ±12.7%), whereas relative humidity in the city environment is 59.3% (S.D.: approximately ±7.9%), thus the relative humidity is 15% higher in the forest environment.

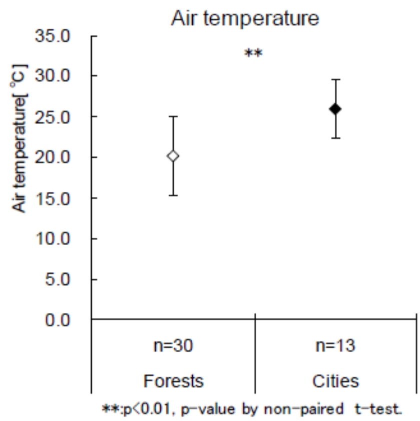

Figure 7. Air temperature (Mean±SD), Forests (20.1±4.77 ºC), Cities (26.0±3.68 ºC).

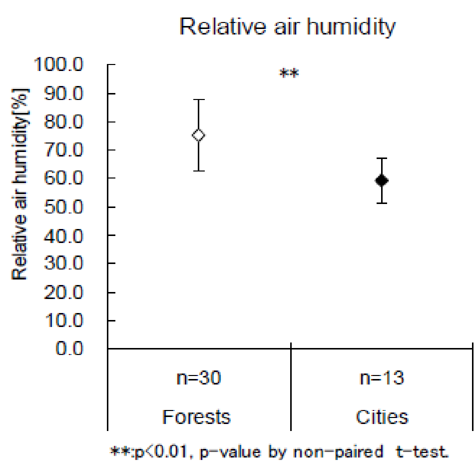

Figure 8. Relative humidity (Mean±SD), Forests (75.1±12.7 %), Cities (59.3±7.9 %).

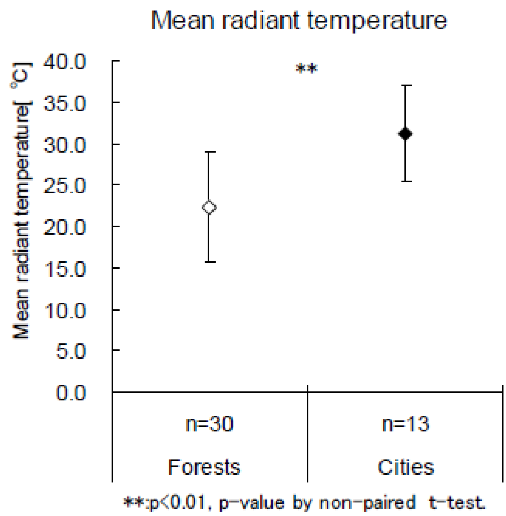

Figure 9. Mean radiant heat (Mean±SD), Forests (22.4±6.6 ℃), Cities (31.3±5.9 ℃).

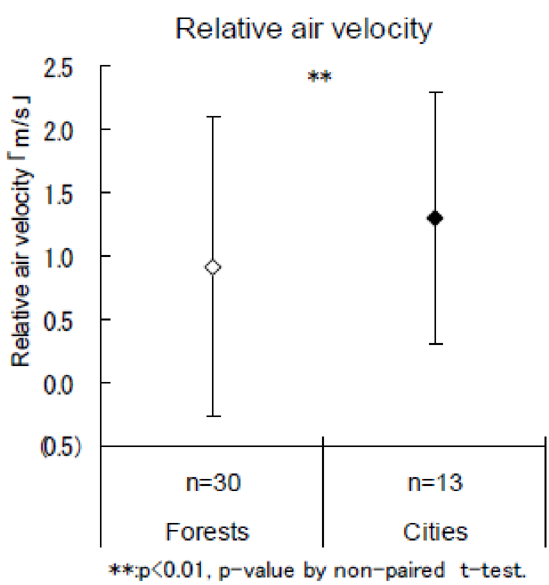

Figure 10. Wind velocity (Mean±SD), Forests (0.92±1.18 m/s), Cities (1.31±0.99 m/s).

The mean radiant heat is radiant energy that is used to raise air temperature, and this has a great influence on our feeling hot and cold in any environment. From Figure 9, the mean radiant heat of the forest environment in the study area was approximately 22.4 ℃ (S.D.: approximately ±6.6 ℃) on average, and that of the city environment was about 31.3 ℃ (S.D.: approximately ±5.9 ℃) on average. These figures of mean radiant heat mean that the latter is 9℃ higher than the former. Finally, from Figure 10, the wind velocity of the forest environment is about 0.92 m/s (S.D.: approximately ±1.18 m/s), and that of the city environment is about 1.31 m/s (S.D.: approximately ±0.99 m/s). So the wind velocity of the forest environment is relatively calm. In general, depending on the type and density of trees, the relative humidity, mean radiant heat and wind velocity were lower, and relative humidity was higher than outside of the forest because evaporation takes place constantly from the leaves of the trees and the soil. It is said that these facts are reasons that brings about healing. We can say that this measurement is an important example toward proving this fact as shown in the scientific data.

The Sound Environment in Forests

As an effective factor of forest therapy, the sound environments also play an important role. However, numerous types of such environments exist, and understanding them objectively is quite difficult. Comfortable sound environments in forests vary widely and may include the chirping of wild birds, sound of a running stream, wind passing through treetops, sound made by insects, and the fact that it is quiet in forests, with each of these differing in quality (Masaki et al. 2007).

For sound environments in forests, the authors took measurements in forest environments at four locations in Nagano Prefecture, which is located in the central portion of Japan (Table-2). Moreover, we also took measurements in the urban areas of Nagano City and Matsumoto City, which are major cities in the prefecture, as the control. Furthermore, we performed psychological experiments using the Semantic Differential (SD) method (Iwashita 1983) on adult male subjects regarding each of the four forest locations and cities to learn how they psychologically captured the sound environments in the forests. A total of 12 subjects were divided into 2 groups with 6 subjects each, and each of the groups performed an observation in a sitting position for 15 minutes (experienced the environment while quietly sitting on a chair) in either a forest or urban environment and were then asked to fill an SD psychological questionnaire. To cancel the order effect, the same experiment was performed on the second day after switching the group that went to a forest on the first day with the other group that went to a city the day before. The measurements of the sound environments were taken during the time period when the subjects were performing the observation experiment in a sitting position on forest bathing.

Materials and Methods

The measurements of the sound environments were taken based on the “Noise levels” index. “Noise levels” are sound pressure levels that have been adjusted by A-weighting and are referred to as “A-weighted sound pressure levels”. The measurements of the “sound levels” were taken using a noise meter CENTER322 (MK Scientific, Inc.), while an IC recorder was used to record sound to grasp different sound types. The Semantic Differential Method (the SD method) in psychological questionnaires usually employs 20 to 30 bipolar adjective pairs to be ranked on a 7-point scale to evaluate the impression of the space experienced. However, this experiment performed psychological evaluation of sound only, by using 2 bipolar adjective pairs, one being “quiet - noisy” and another being “comfortable - uncomfortable” to evaluate the overall impression of the space.

Table 2 Summary of study areas

Name of study area	Agematsu	Shinanomachi	Iiyama	Minamiminowa
Location	Agematsu town	Shinano town	Iiyama city	Minamiminowa village
Date of study (2005)	July 7-8	August 10-11	August 30-31	September 14-15
Characteristic of study area	Within Akazawa recreation forest	Nainotaki course	Numanohara wetland	Oshiba plateau
State of forest	More than 200 years old natural forest	Broad-leaved secondary forest	Broad-leaved secondary forest	double-storied plantation forest
Sound of first day	Running stream	Running stream	Cicada and bird	calm
Sound of second day	Running stream	Cicada	Cicada and bird	calm

Results and Discussion

The average sound volumes obtained in forests at four locations are shown in Figure 11. Also, the average volumes obtained in the urban areas as the control are shown in Figure 12.

Except for the value of the forest environment in Shinano-machi exceeding that of the urban environment in Nagano City, the noise levels were lower in forest environments. The sound types differed in forests depending on the survey location, with the “sound of a running stream” being audible in Agematsu-cho, “cicada sound” in Shinano-machi, “chirping of wild birds” and “cicada sound” in Iiyama City, and occasional “chirping of wild birds" and “cicada sound” during silence in Minamiminowa-mura. In the urban areas of Nagano City and Matsumoto City, the sound environment consisted of artificial sound, primarily the operating sounds of automobiles. On the other hand, regarding changes in noise levels, forest environments were revealed to have smaller changes than city environments except for large changes before and after cicada sound in Iiyama City.

The results of the psychological experiment using the SD method are shown in Figure 13. Regarding the “quiet - noisy” impressions, urban areas gave an impression of being “noisy” at all survey locations, while forests gave an impression of being “quiet”. It is interesting that the forests in Shinano-machi, which scored the highest noise level, was evaluated as “neither” though urban environments with noise levels lower than Shinano-machi were evaluated as giving an impression of being “quite noisy”.

Regarding the “comfortable – uncomfortable” impressions, forest environments gave impressions of being more comfortable compared to urban areas.

Therefore, it can be said that humans develop a feeling of being comfortable in the quiet sound environments of forests with low noise levels and small changes in noise levels. Furthermore, it can be inferred that natural sounds such as “cicada sound” do not give an impression of being noisy or uncomfortable even if they are higher in noise level compared to artificial sounds such automobile sounds.

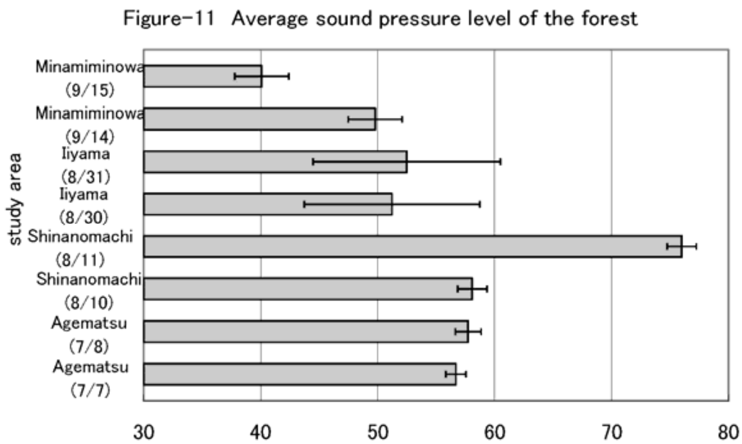

Figure 11. Average sound pressure level of the forest.

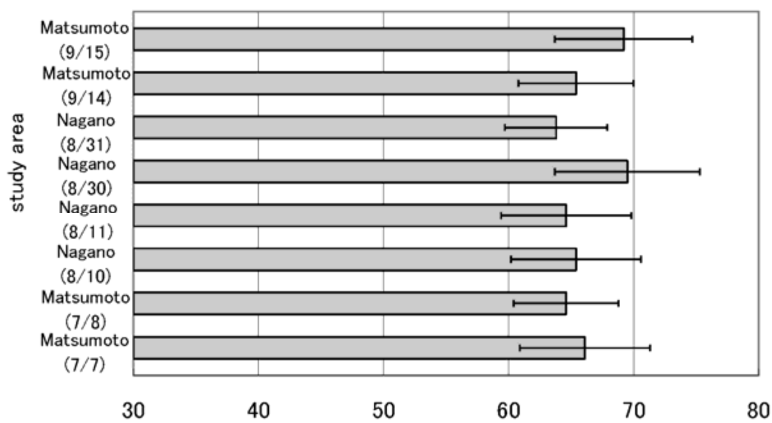

Figure 12. Average sound pressure level of the city.

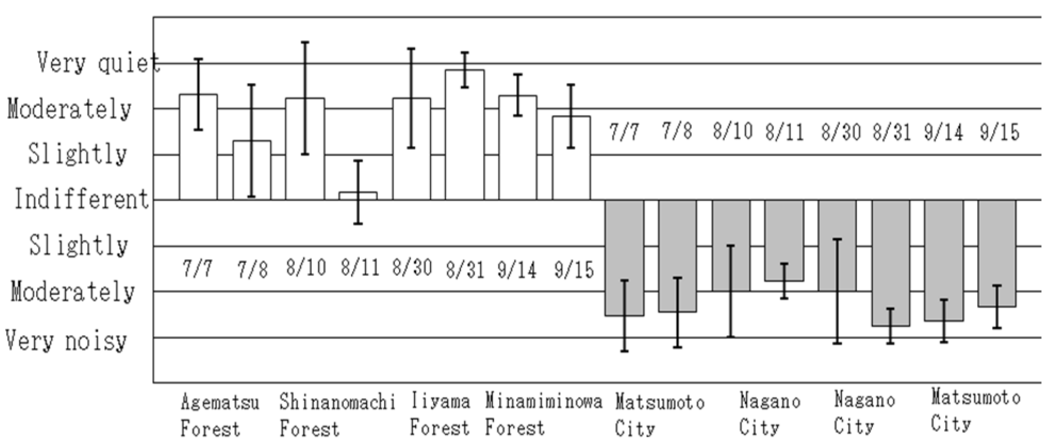

Figure 13. Subjective evaluation of “quiet-noisy”.

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Chapter 3

Phytoncides in Forest Atmosphere

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Abstract

The major phytoncides found in coniferous and broad-leaved forests are α-pinene and isoprene, respectively. The amounts of these phytoncides vary between seasons, increasing from June to September for the summer, and decreasing for the winter. The patterns of diurnal variation differ between the different substances; the amounts of monoterpenes, such as α-pinene, are higher during the night than during the day whereas the amounts of isoprene are the opposite. In a forest, the horizontal distribution of phytoncides during the day tends to be more concentrated near the center of the forest than its edges and their vertical distribution tends to be more concentrated closer to the ground.

Keywords: phytoncide,α-pinene, isoprene, seasonal variation, forest air

1. Introduction

Forest air is very refreshing and when we visit a forest for a stroll, sometimes we catch a breeze carrying a fresh scent and are overcome with a feeling of "relief." Forest air is clean and refreshing because tree leaves clean the air by attracting and absorbing waste gases or other pollutants while releasing fresh oxygen into the air. Another possible reason for the refreshing feeling of forest air is the effect of phytoncides, volatile substances released into the air by plants. The following sections describe the characteristics of phytoncides found in

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forests with different tree species compositions, while focusing on actual data of the amounts of phytoncides.

2. What Are Phytoncides?

The word "phytoncide" was coined by Dr. B. P. Tokin, a Russian embryology researcher in around 1930; "phyton" originates from the Greek word for "plant," and "cide" from the Latin word for "killing other organisms." Dr. Tokin found that when the minced leaves of Sakhalin fir (*Abies sachalinensis*) and pines, wasabi (*Wasabia japonica*), or grated garlic were placed near protozoa, such as amoebae, or *Shigella*, these protozoa and bacteria were exterminated by volatile substances released from the plant materials. He named these substances "phytoncides." It is thought that plants give off phytoncides as a means of self defense, in other words, as plants cannot run away from leaf-eating insects they need to protect themselves. Thus, it is thought that plants give off phytoncides, which act as an insect repellant, antimicrobial agent, or inhibitor to other plants' growth, in order to expand their own living space. The notion of phytoncides, according to Dr. Tokin, encompasses not only the substances released by plants but also the substances secreted by microbes such as fungi; moreover, both scented volatile substances and scentless nonvolatile substances are treated as phytoncides. The range of effects by phytoncides is not limited to repelling protozoa and microbes but also insects and animals. Today, the range of meaning for the word "phytoncide" has been further extended to include not only substances that "kill" something, but also those substances that give beneficial effects to the recipients. The word "phytoncide," if translated into Japanese, means "bioactive substance produced by plants." A lot of research has been done on phytoncides. The chemical actions of phytoncides discovered so far include antimicrobial action, growth control activity in plants, and insect or animal attraction/repulsion effects. Moreover, phytoncides have been found to exert refreshing effects on humans. The phytoncides so far discovered include volatile or liquid substances and also solids; those that directly come in contact with the body while walking in a forest are volatile phytoncides released into the air by plants [1].

3. Substances which Are Phytoncides in Forests

The phytoncides that we can experience in a forest are a mixture of volatile substances released by tree leaves, tree stems, tree barks, shrubs, underbrush, litters, mushrooms, and bryophytes. In previous studies, many types of compounds, including phenols and hydrocarbons, have been identified as phytoncides that can be found in forests. Among these compounds, terpenoids are a major component [2].

3.1. Terpenoids

The phytoncides found in a forest are mainly C10 to C15 monoterpenes, sesquiterpenes, and C5 hemiterpenes. Trees synthesize various volatile substances in their leaves, stems, and xylem; these substances are commonly called "essential oils". The amounts and compositions of essential oils vary between different tree species. However, in all plants the leaves have the highest content of essential oil. Compared with broad-leaved trees, conifers have a higher essential oil content. Among native trees in Japan, the highest essential oil contents are seen in *Abies sachalinensis,* followed by *Thuja standishii, Chamaecyparis obtusa, and Cryptomeria japonica*. Compared with conifers, broad-leaved trees generally have a low essential oil content although some trees, including *Eucalyptus* and *Lauraceae* (*Cinnamomum camphora, Cinnamomum tenuifolium*, and *Machilus thunbergii*), contain 2 mL/100 g (dried leaves) or more essential oil.

In contrast, broad-leaved trees such as *Quercus acutissima, Quercus serrata, Quercus myrsinaefolia,* and *Castanopsis sieboldii* release large amounts of isoprene which is a hemiterpene, a subtype of terpenes. Compared with monoterpenes, which are released in large amounts by conifers, isoprene has a lower boiling point and a smaller molecular weight. It is also said that the form in the plant body differs between isoprene and monoterpenes.

4. Method of Quantifying Phytoncides

The amount of substances released from the leaves of a conifer is about 1–10 μg/(g × h) (the amount [μg] of substances released from 1 [g] of leaves per hour [h]), which is very small, and depends on the temperature and illuminance. It is known that the amounts released increase as the temperature rises and the illuminance increases [3], while the amount detectable in the forest decreases as the substances released from the leaves are exposed to the effects of wind, temperature, UV light, and ozone, amongst other things. As the abundance of phytoncides in a forest is said to be just a few ppb to several hundred ppb at most, a large amount of air needs to be collected in order to obtain sufficient data. Picture 1 shows the typical method of collecting phytoncides. This sampling method is called the "active sampling method," and uses adsorbents. Because measurements take place outdoors, a very portable device is commonly used and the phytoncides are sampled at a height of 1.2 m above ground, simulating the height of the face of a person walking in a forest. The data obtained by this method are presented in the following sections.

Picture 1. Sampling of phytocides in forest atmosphere.

5. Quantification of Phytoncides in a Forest

Broad-leaved forests in Japan are characterized by *Fagus crenata* (Siebold's beech, buna in Japanese), *Quercus serrata* (konara in Japanese), *Castanopsis sieboldii* (sudajii in Japanese), *Quercus myrsinaefolia* (shirakashi in Japanese), *Betula platyphylla var. japonica* (shirakamba in Japanese), *Quercus mongolica* (mizunara in Japanese) and so on. Coniferous forests are characterized by *Cryptomeria japonica* (Japanese cedar, sugi in Japanese), *Chamaecyparis obtuse* (hinoki cypress, hinoki in Japanese), *Pinus densiflora* (Japanese red pine, akamatsu in Japanese) and so on. There are also mixed forests that contain both coniferous and broad-leaved trees. The appearance of forests changes in many ways depending on the location and the altitude; similarly, the phytoncides found in forests are diverse. The following sections introduce data obtained from forests with different compositions of tree species.

5.1. Phytoncides Found in a Forest Mainly Consisting of Conifers

Figure 1 shows the data obtained in the analysis of substances collected from a Japanese red pine forest and a hinoki cypress forest: mainly monoterpenes were detected, including α-pinene, camphene, and β-pinene. Particularly in coniferous forests, the major component was characteristically α-pinene. Table 1 shows the result of analysis of the samples collected in a typical Japanese cedar forest and a hinoki cypress forest. The detected substances were similar, but the composition was slightly different between the two forests; the total amount of phytoncides tended to be larger in the hinoki cypress forest than in the Japanese cedar forest.

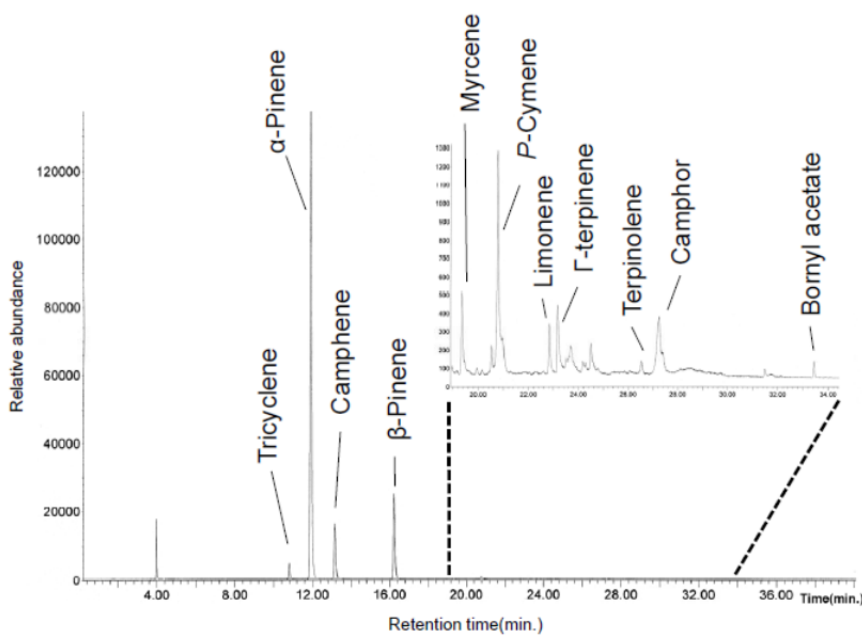

Figure 1. Selected ion chromatogram (m/z93) of an air sample collected in Japanese red pine and hinoki cypress forests.

Table 1. Concentrations of terpenoids in several kinds of coniferous forests in July

Compounds	Concentrations (ng/m³)		
	Japanese cedar (*Cryptomeria japonica*)	Hinoki cypress (*Chamaecyparis obtusa*)	Japanese red pine (*Pinus densiflora*)
Isoprene	205	nd	nd
Tricyclene	234	1704	nd
α-Pinene	6320	6025	1350
Camphene	1318	550	nd
β-Pinene	209	710	172
Myrcene	412	nd	nd
δ-3-Carene	9	166	111
α-Terpinene	72	nd	1583
p-Cymene	129	407	nd
D-Limonene	35	1355	114
1,8-Cineole	nd	nd	nd
γ-Terpinene	24	nd	nd
Terpinolene	nd	1804	nd
Camphor	nd	nd	nd
Bornyl acetate	7	nd	nd

nd: not detected.
These values are indicated equivalent to α-pinene.
Sampling in July for 22hrs.

In forests mainly consisting of hinoki cypress, the amount of α-pinene was particularly high, followed by terpinolene, tricyclene, limonene, and so on, while in the forests mainly consisting of Japanese red pine, α-terpinene was the major component, followed by α-pinene and β-pinene.

In the forests mainly consisting of Japanese cedar, α-pinene was the major component, and camphene was the secondary component. These data indicate that the detected major components and their amounts are different for coniferous forests if they have different compositions of tree species. Phytoncides are released from various plants in forests, but the majority of phytoncides are released from tree leaves and the leaves of different tree species contain different types of essential oils at different concentrations. This is probably the reason why different phytoncides are detected in coniferous forests with different compositions of tree species [4].

5.2. Phytoncides in a Forest Mainly Consisting of Broad-Leaved Trees

Forests of broad-leaved trees typically contain various tree species, and thus the difference in the composition of phytoncides between the broad-leaved tree species has not been clearly characterized.

In previous research, isoprene was detected as the major component in broad-leaved forests, with α-pinene being the major component in coniferous forests. This observation is almost consistent with the data obtained in our research, but with some exceptions. Table 2 presents an overview of substances detected in a typical broad-leaved forest (*Fagus crenata, Quercus mongolica and Betula platyphylla var. japonica, Quercus myrsinaefolia and Quercus serrata*).

Table 2. Concentrations of terpenoids in several kinds of broad-leaved forests in August

Compounds	Concentrations(ng/m³)		
	Buna(*Fagus erenata*)	Mizunara(*Quercus mongolica*), Shirakamba(*Betula platyphylla*)	Shirakashi(*Quercus myrsinaefolia*), Konara(*Querucus serrata*)
Isoprene	49948	2268	40
Tricyclene	nd	10	43
α-Pinene	1402	48	181
Camphene	nd	13	22
β-Pinene	nd	11	6
Myrcene	nd	1	0.9
δ-3-Carene	nd	1	nd
α-Terpinene	nd	0.5	3
p-Cymene	nd	3	5
D-Limonene	140	2	nd
1,8-Cineole	nd	nd	nd
γ-Terpinene	nd	1	nd
Terpinolene	177	0.8	nd
Camphor	nd	2	2
Bornyl acetate	nd	0.7	nd

nd: not detected.
These values are indicated equivalent to α-pinene.
Sampling in August for 22hrs.

Although the percentage of monoterpenes, the major component in coniferous forests, was small, the isoprene content was particularly high in the broad-leaved forests. It was previously reported that the major component of substances released from broad-leaved trees is isoprene [5]. The annual emissions of biogenic volatile organic carbon (BVOC), such as isoprene, produced and released from plants are estimated to be greater than the annual emissions of the volatile organic carbons from human activities. Among them, in particular, the estimated amount of isoprene emissions accounts for as much as 50% of the total BVOC emissions [6]. This value is surprisingly high.

It is not clear why plants release such large amounts of isoprene, although there are various theories. Some argue that isoprene acts as a signal for the opening/closing of flowers while others argue that isoprene is involved in the nitrogen cycle, isoprene has ozone quenching properties, or isoprene protects plant leaves against heat stress [7].

Environmental factors have a significant effect on isoprene emissions. It is known that, under high humidity conditions (for example, after rain), tree leaves vigorously release volatile substances [8]. In fact, the data obtained in forests show that the emission of isoprene increase when it rains.

5.3. Seasonal and Diurnal Variation as to the Amount of Phytoncides [9]

The amounts of substances produced within the bodies of trees vary between seasons and accordingly, the amount of phytoncides released from leaves also varies between seasons. Generally, the level of phytoncide emissions is high during the summer and low during the winter. Figure 2 shows the seasonal variation in the amount of phytoncides found in a Japanese red pine forest. Although data from different years need to be evaluated collectively because volatile substances are susceptible to environmental factors (temperature, humidity, wind velocity, UV light, and so on), the amounts of phytoncides tend to rise quickly in April and May, and the highest amounts of phytoncides in a year occur between June and August when the temperatures are high. It is known that the concentration of volatile substances in a forest is greatly influenced by environmental factors such as humidity, temperature, and UV light, and it has been demonstrated that the concentration of volatile substances has a high positive correlation with temperature.

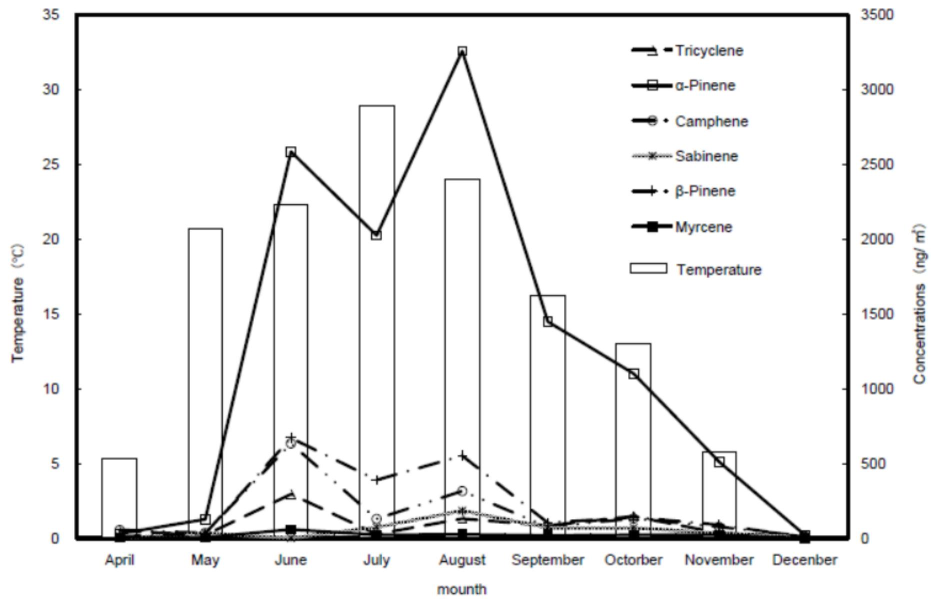

Figure 2. Seasonal variation in the concentration of terpenoids and in ambient temperature in a Japanese red pine forest at 9:00 am.

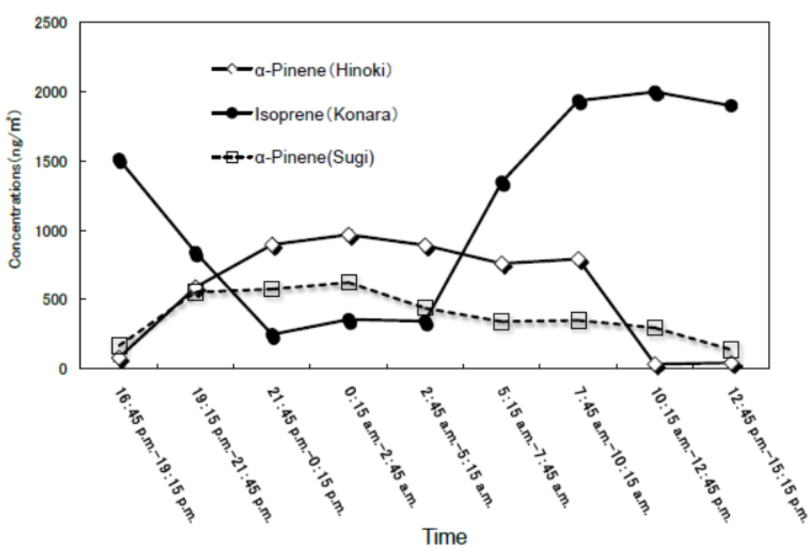

Figure 3. Diurnal variation in the concentration of terpenoids in the air of coniferous (hinoki, sugi) and broad-leaved (konara) forest in July.

The diurnal variation in the amounts of phytoncides in a forest is explained below. In a forest, the flow of air changes all the time due to the effects of temperature and wind. Data on the diurnal variation collected at a fixed height from the ground are presented below. Figure 3 shows the changes over 24 hours in the amounts of phytoncides in a forest. Interestingly, the pattern of variation tends to differ depending on the substance type. The amount of α-pinene mainly detected in confers increases from the evening to midnight, with the highest amount occurring around the latter time. Compared with night time, the amount of α-pinene is low during the day. The amounts of α-pinene tend to increase temporarily in the morning. It feels great to walk through a morning mist in a forest after getting up early, and one of the reasons for this may be the increased amounts of phytoncides in the forest. Regarding the distribution of phytoncides in coniferous forests during a day, previous studies have reported that the amounts of scented substances are greater in the morning than in the afternoon [10].

Isoprene, which is mainly detected in broad-leaved trees, shows a different pattern; the amount of isoprene tends to be higher during the day and low during the night. The reason for these differences is not clear, but may be due to the differences in the biosynthesis mechanisms within the plant body or a difference in the release mechanism [11].

5.4. Horizontal/vertical Distribution of Phytoncides

In a forest, the distribution of scents differs in the horizontal and vertical directions. The density of trees is low at the edges of a forest and high at its center, and because phytoncides are mainly released from the tree leaves, the amounts of phytoncides are higher in the areas where the tree density is high.

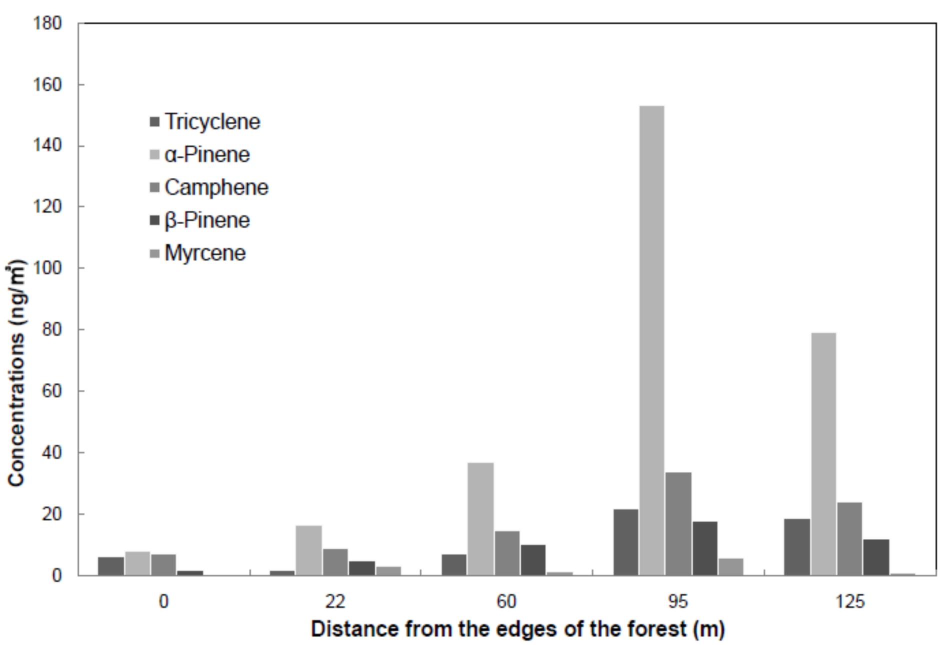

Figure 4. Horizontal distribution of terpenoids in the air of Japanese red pine forest at 9:00 am – 16:00 pm in July.

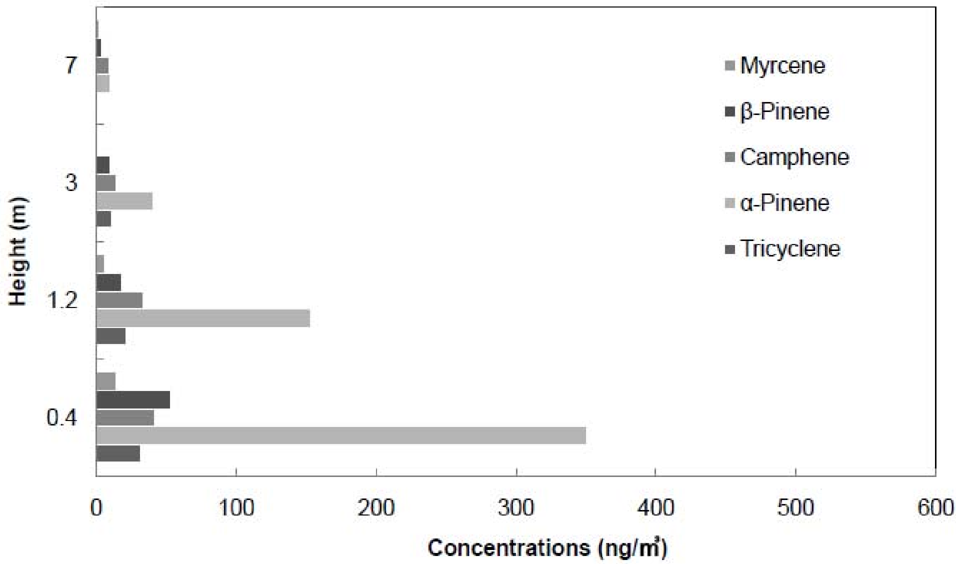

Figure 5. Vertical distribution of terpenoids in the air of Japanese red pine forest at 9:00 am – 16:00 pm in July.

Figure 4 shows data based on actual measurements obtained from a Japanese red pine forest. The data show that the amounts of phytoncides are small at the edges of the forest, and gradually increase toward the center of the forest. This may be because the tree density is higher at the center of a forest compared with its edges, and may additionally be related to environmental factors, for example, the wind being weaker at the center of a forest. If phytoncides are considered one of the factors related to the healing effect of forests, it is probably more effective to walk deeper into a forest than just looking at the forest from a distance.

The vertical distribution of phytoncides has seldom been reported. The data collected in a Japanese red pine forest show that, during the day, the amount of phytoncides decreases as the height from the ground increases, i.e., the highest amounts of phytoncides were observed close to the ground. The reason why the amount of phytoncides decreased with increasing height from the ground during the day is probably that the UV light is more intense near the canopy, and the phytoncides are degraded by UV light. In addition, the wind is weaker than in the canopy layer, and because phytoncides are heavier than air they tend to accumulate near the ground. The phytoncides released from underbrush, dead leaves, and bryophytes living on the forest floor must also be taken into consideration [4].

Conclusion

The healing effect of forests is probably produced by the integration of the multi-dimensional functions that forests possess. Phytoncides probably have an important role as one of these functions. However, as stated above, the amounts of phytoncides detected in a forest are very small, and their amounts and composition vary depending on the composition of tree species in the forest, the season, and the time of the day. Further research is needed to elucidate how the composition of tree species in forests and environmental factors are related with the composition and the amounts of phytoncides released from plants, and to find the conditions that allow us to experience phytoncides more effectively.

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Chapter 4

Psychological Evaluations of Forest Environment and the Physical Variables

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Abstract

The present study aimed to clarify the relationship between psychological responses to forest and urban environmental settings and the physical variables that characterize these environments, by examining the psychological responses of 168 subjects to their physical environment. Field experiments were conducted in 14 forests and 14 urban areas across Japan. The semantic differential (SD) method was employed in which a questionnaire was administered to subjects prior to their walks in the forests and urban areas. In addition, the profile of mood states (POMS) questionnaire was administered before and after the walks, as well as before and after they sat and viewed the forest and urban landscapes. The environmental variables measured were air temperature, relative humidity, radiant heat, wind velocity, and two indices of thermal comfort [predicted mean vote (PMV) and predicted percentage dissatisfied (PPD)]. Responses to the SD questionnaire indicated that compared to urban settings, forest settings are perceived as being significantly more enjoyable, friendly, natural, and sacred. The POMS measures of tension and anxiety (T-A), depression and dejection (D), anger and hostility (A-H), vigor

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(V), confusion (C), fatigue (F), and total mood disturbance (TMD) showed significant differences between the forests and urban areas. These results strongly support the suggestion that forest settings have attention restoration effects. The psychological **responses** to physical environments were also significantly related to air temperature, relative humidity, radiant heat, wind velocity, PMV, and PPD. The results of this study might be useful in designing restoration environments in urban areas.

Keywords: Therapeutic effects, forest environments, Forest bathing, SD (semantic differential) method, POMS (profile of mood states), PPD (predicted percentage dissatisfied)

1. Introduction

Noise pollution, air pollution, work pressure, and other stressors of urban life are increasingly driving humans to seek some form of stress relief (Frumkin, 2001). As a result, interest in environmental stress experienced by urban dwellers is growing (Ulrich et al., 1991). Generally, natural environments including urban parks of everyday surroundings, and artificial constructed forests are associated with stronger positive health effects compared to urban environments (Velarde et al., 2007), and outdoor recreation in a "green" environment has been shown to relieve stress in urban dwellers (Knopf, 1983). Ewert (1986) proposed that forest environments should be viewed as "a great health machine," and activities conducted in forest settings reportedly provide both preventive and therapeutic health benefits (Kaplan, 1995).

With this background, the European Union initiated the Forests, Trees, and Human Health and Well-Being (COST action E39) study, which was conducted between 2004 and 2008. This study aimed to increase knowledge on the contribution of natural environments to the health and well-being of people residing in Europe. It also aimed to improve the description and evaluation of the relationship of forests and trees with human health (Karjalainen et al., 2010). The International Union of Forest Research Organizations (IUFRO) has also initiated a special project (task force) investigating the relationship between forests and human health (Karjalainen et al., 2010). In response to these initiatives, the Therapeutic Effects of Forests project was started in 2004 in Japan (Park et al., 2010). As a part of this effort, the Japanese Society of Forest Medicine was established in 2007 under the Japanese Society for Hygiene with the purpose of promoting research in the field of forest medicine, including investigations on the effects of forest bathing trips and the therapeutic effects of forests on human health (Park et al., 2010). Based on empirical studies, nature environments have been shown to provide better emotional, physiological, and restoration than urban environments (Hartig and Staats, 2003). Several studies conducted in different countries have reported that compared to urban environments, natural environments can better enhance human moods (Hartig et al., 2003; Laumann et al., 2003; Morita et al., 2006) and work performance (Shin, 2007). In the aspects of physiological responses in nature environments, it is more difficult to control the experimental conditions in the field than in the laboratory. However, the rapid progress of technology has enabled the application of certain physiological measurements to experiments in the field (Tsunetsugu et al., 2010). Recently studies reported lower concentrations of cortisol, lower blood pressure, and lower pulse rates, decreased sympathetic nerve activity (as measured by the low frequency/high frequency (LF/HF) component of heart rate variability (HRV)), enhanced parasympathetic nerve activity (as measured by the HF component of HRV), and higher levels of natural killer (NK) cell activity (a typical index of human immune function) in the human body when the subjects are in forest environments as opposed to when they are in urban environments (Li et al., 2008; Lee et al., 2009; Park et al., 2009, 2010). The fact that people perceive environments in their complete aspects is a widely known fact. This is why many studies assign their purpose in revealing the relationship of humans and their environments in their complete aspects. I also believe that the fact of the requirement of an analytical approach is also an important fact. The final aim of the Therapeutic Effects of Forests project is to design a restorative forest environment in an urban natural setting. Several studies have been conducted to identify the various elements that should be included in such environments. However, few have attempted to study restoration environments with a focus on the influence of physical variables of the environment on psychological responses. If the results obtained through this thoroughly structured experimental design are accumulated, it is believed to be able to reveal the mutual relationships of each variable. In this study, we measured the psychological responses of 168 subjects to their physical environment in 14 forests and 14 urban areas using the semantic differential (SD) method and the profile of mood states (POMS) questionnaire. We also measured six physical variables of the environment within these areas. The aim of this study was to clarify the influence of forest and urban settings on the psychological well-being of humans by conducting field experiments at 14 forests and 14 urban sites across Japan. In addition, we attempted to identify the physical variables within the environments that were responsible for improving the psychological well-being. The results of this study can be used for designing restoration environments in urban areas for relaxation. This study will firstly discuss the results of the psychological evaluations in the sequence of the SD method and POMS (profile of mood states), followed by the discussion of results of physical variables. Lastly, the relationship between psychological evaluations and the physical variables will be discussed.

2. Materials and Methods

2.1. Experimental Design

The study areas were located at 14 forests and 14 urban sites across Japan (Figure 1). The experimental locations used in the study are listed in Table 1. The measurement of environmental variables have been conducted for 2 days during the most representative term of Japanese summer, as it was done for the psychological measurement. Each experiment involved 12 male university students with no reported history of physical or psychiatric disorders. A total of 168 subjects (age, 20.4 ± 4.1 years) were included over 14 experiments. The study was conducted according to the regulations of the Institutional Review Committee of the Forestry and Forest Products Research Institute in Japan. One day before the experiments began, the subjects were informed of the aim and experimental procedures of the study and their consent was obtained. After this orientation, the subjects previewed the selected forests and urban areas. A practice session to familiarize the subjects with the measurement procedures was then conducted at their place of accommodation. Identical single rooms were prepared and identical meals were provided to each subject for the duration of the study period in order to control these background environmental conditions.

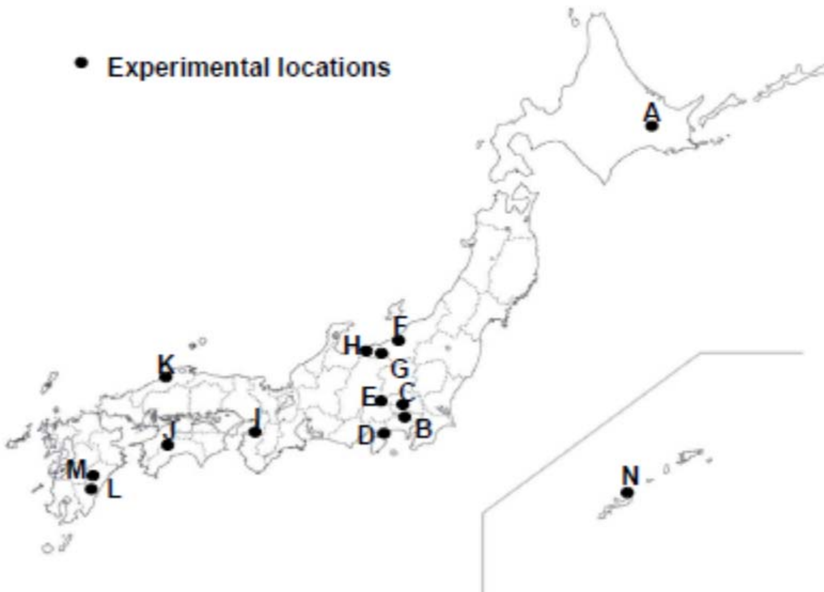

Figure 1. Map of experimental locations.

Figure 2. Photos showing the forest sites used for the “Viewing” and “Walking” phases of the experiments. Upper left: “Viewing” at forest setting, Upper right : “Walking” at forest setting Lower left : “Viewing” at urban setting, Upper right : “Walking” at urban setting

Table 1. Experimental locations

*Experimental lacation should say: Experimental location

	A	B	C	D	E	F	G
Experimental lacation	Hokkaido Tsurui-mura	Kanagawa Pref. Atsugi-shi	Tokyo Hinohara-mura	Shizuoka Pref. Kawazu-cho	Yamanashi Pref. Yamanashi-shi	Niigata Pref. Tsunan-machi	Nagano Pref. Kijimadaira-mura
Psychological experiment schedule	Sept. 12□ Sept. 14 of 2006	Aug. 8□ Aug. 11 of 2006	Sept. 4□ Sept. 7 of 2006	Sept. 19□ Sept. 22 of 2006	Aug. 22□ Aug. 25 of 2006	July 18□ July 20 of 2006	July 25□ July 28 of 2006
Number of subjects	12	12	12	12	12	12	12
Average age of subjects	20.7 (±1.3)	21.6 (±2.1)	21.4 (±0.9)	20.3 (±0.6)	21.0 (±0.9)	20.7 (±1.8)	22.8 (±1.2)
Physical environments experiment schedule	Sept. 13 of 2006	Aug. 10 of 2006	Sept. 6 of 2006	Sept. 11□ Sept. 22 of 2006	Aug. 23 of 2006	July 19□ July 20 of 2006	July 26 of 2006
	H	I	J	K	L	M	N
Experimental lacation	Nagano Pref. Otari-mura	Wakayama Pref. Koya-cho	Kochi Pref. Yusuhara-cho	Shimane Pref. Iinan-cho	Miyazaki Pref. Aya-cho	Kagoshima Pref. Kirishima-shi	Okinawa Pref. Kunigami-son
Psychological experiment schedule	Sept. 5□ Sept. 8 of 2006	Aug. 1□ Aug. 4 of 2006	May 16□ May 19 of 2006	Sept .19□ Sept. 21 of 2006	July 11□ July 13 of 2006	July 4□ July 6 of 2006	Feb. 13□ Feb. 15 of 2007
Number of subjects	12	12	12	12	12	12	12
Average age of subjects	20.7 (±1.2)	21.8 (±1.3)	21.2 (±0.9)	20.9 (±1.7)	21.8 (±1.5)	21.9 (±0.6)	22.4 (±0.5)
Physical environments experiment schedule	Sept. 6 of 2006	Aug. 23 of 2006	May 18 of 2006	Sept. 20□ Sept. 21 of 2006	July 12□ July 13 of 2006	July 5□ July 6 of 2006	Feb. 15 of 2007

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The subjects were randomly divided into two groups. On the first day of the experimental period, 6 subjects were sent to a forest area and the remaining 6 (controls) were sent to an urban area. On the second day, the subjects were sent to the opposite area to eliminate bias of order. Upon arrival in the given area, the subjects sat on chairs and viewed the landscape for 15 minutes ("Viewing" phase) before noon; they then walked around the area for 15 minutes ("Walking" phase) in the afternoon (Figure 2). On site J, a pleasant walking experiment was impossible due to rainy weather the previous day. A walking experiment has not been conducted on site J

For psychological evaluations, the SD method (Osgood, 1952) and POMS (McNair and Lorr, 1964) questionnaire were used. The SD method tests the subjective spatial impressions of subjects through a questionnaire with 25 pairs of opposing adjectives, each of which was evaluated on a 13-point scale. The measurements were recorded for one subject at a time after the "Walking" phase of the study between 14:30 and 15:20.

The POMS is a well-established, factor analytically derived measure of psychological distress, and its high level of reliability and validity have been documented (McNair and Lorr, 1964). POMS tests can simultaneously evaluate 6 measures of mood: tension and anxiety (T-A), depression (D), anger and hostility (A-H), vigor (V), confusion (C), fatigue (F), and total mood disturbance (TMD). We used T-scores of POMS for the analysis. For this study, we used the Japanese version of POMS (Yokoyama, 1990), which consists of 30 items.

The first and second POMS measurements were performed before (10:40–11:30) and after (11:00–11:50) the "Viewing" phase of the study. The third and fourth measurements were performed before (14:10–15:00) and after (14:30–15:20) the "Walking" phase of the study. These measurements were performed for one subject at a time. The Steel-Dwass test was used to analyze the psychological responses based on the following 8 conditions: (1) survey responses before the “Viewing” phase in the forest and urban areas, (2) survey responses after the “Viewing” phase in the forest and urban areas, (3) survey responses before the “Walking” phase in the forest and urban areas, (4) survey responses after the “Walking” phase in the forest and urban areas, (5) survey responses before and after the “Viewing” phase in forests, (6) survey responses before and after the “Walking” phase in forests, (7) survey responses before and after the “Viewing” phase in urban areas, and (8) survey responses before and after the “Walking” phase in urban areas. Statistical analysis of physiological data was processed using EXCEL 2007 (Microsoft Inc.). A p value of <0.05 was considered significant.

2.2. Measurement of Physical Variables in Each Environment

Air temperature, relative humidity, radiant heat, wind velocity, and two indices of thermal comfort— predicted mean vote (PMV) and predicted percentage dissatisfied (PPD)— were measured at each of the forest and urban sites. These measurements were performed at or close to the areas where the psychological measurements were performed. PMV is an index for evaluating the compound effect of 6 factors related to the thermal environment (air temperature, relative humidity, wind velocity, radiant heat, amount of clothing worn, and metabolism level), and was adapted as an ISO standard to be used as an index of thermal comfort (ISO7730, 2005). PPD is a predicted value calculated from PMV. It predicts the percentage of people dissatisfied with the thermal conditions of their surroundings (ISO7730, 2005). Assumptions relating to the amount of clothing worn and the metabolic levels of the subjects are required for calculating PMV and PPD. In this study, the amount of clothing worn was specified as light summer clothes (clo: 0.5) in July and August and as autumn clothes (clo: 1.0) in the other months surveyed. In terms of the metabolic level, a standing level (met: 2.0) was used for the “Walking” phase of the study. A commercially available PMV meter (Amenity meter, AM-101, Kyoto Electronics Manufacturing Co. Ltd., Japan) was used to measure the air temperature, relative humidity, radiant heat, wind velocity, PMV, and PPD; measurements were recorded every 10 min at the sites surveyed. A portable weather meter (Pocket weather tracker, Kestrel 4000, Nielsen Kellerman Corporation, USA) was used for measuring barometric pressure as well as for measuring the temperature and relative humidity in urban areas.

2.3. Statistical Analysis

The Steel-Dwass test was used to analyze the POMS subscales based on the following 8 conditions: (1) survey responses before the “Viewing” phase in the forest and urban areas, (2) survey responses after the “Viewing” phase in the forest and urban areas, (3) survey responses before the “Walking” phase in the forest and urban areas, (4) survey responses after the “Walking” phase in the forest and urban areas, (5) survey responses before and after the “Viewing” phase in forests, (6) survey responses before and after the “Walking” phase in forests, (7) survey responses before and after the “Viewing” phase in urban areas, and (8) survey responses before and after the “Walking” phase in urban areas.

For the comparison of SD method scales between forest and urban settings, a Wilcoxon rank sum test was used. Principal component analysis (using varimax rotation) was performed to analyze the sensory evaluations reported using the SD method.

Statistical analysis of physiological data was processed using EXCEL 2007 (Microsoft Inc.). A p value of <0.05 was considered significant.

3. Results

3.1. Results of Psychological Evaluations Performed Using the SD Method

Figure 3 shows the SD profile curve of the average values reported by 168 subjects over 14 experiments after the "Walking" phase of the study in forest and urban areas. The figure indicates that compared to urban environments, the forest environments are perceived significantly more times as "natural (vs. artificial)," "healthy (vs. unhealthy)," "beautiful (vs. ugly)," "calm (vs. restless)," "enjoyable (vs. non enjoyable)," "gentle lighting (vs. too bright)," "quiet (vs. noisy)," "refreshing (vs. dull)," "open (vs. closed)," "pleasing sound (vs. irritating noise)," "comfortable (vs. uncomfortable)," "three-dimensional (vs. flat)," "friendly (vs. unfriendly)," "enchanted (vs. disenchanted)," "cool (vs. warm)," "secure (vs. insecure)," "wet (vs. dry)," "soothing (vs. awakening)," "fragrant (vs. malodorous)," "unique (vs. nondescript)," "orderly (vs. chaotic)," and "odorless (vs. smelly)." In contrast, descriptions such as "bright (vs. dark)" and "animated (vs. still)" are reported less often for forest environments than for urban environments.

The results of the principal component analysis are shown in Table 2. When the proper value was assumed to be 1 or more, seven repetitions resulted in an end of rotation and three factors were extracted. For the first principal component, variables with a factor loading of 0.6 or more, i.e., "enjoyable (vs. non enjoyable)" (0.86), "friendly (vs. unfriendly)" (0.80), "comfortable (vs. uncomfortable)" (0.76), "calm (vs. restless)" (0.73), "refreshing (vs. dull)" (0.70), "secure (vs. insecure)" (0.69), "pleasing sound (vs. irritation nose)" (0.67), "beautiful (vs. ugly)" (0.65), "fragrant (vs. malodorous)" (0.65), and "healthy (vs. unhealthy)" (0.64), were extracted, and the first principal component was then designated as "the perception of an environment as enjoyable and friendly." For the second principal component, "natural (vs. artificial)" (0.77), "enchanted (vs. disenchanted)" (0.75), "quiet (vs. noisy)" (0.70), "gentle lighting (vs. too bright)" (0.62), and "soothing (vs. awakening)" (0.65) were extracted, and the second principal component was designated as "the perception of an environment as natural and enchanted." For the third principal component, "bright (vs. dark)" (0.75) was extracted.

Figure 4 shows the results of principal component factoring based on the results obtained from the SD method questionnaire comparing psychological responses to forest environment with those to urban environments. The first principal component (the perception of an environment as enjoyable and friendly) scored significantly higher in forest settings than in urban settings. The scores for the second principal component (the perception of an environment as natural and enchanted) were also higher in forests settings than in urban settings.

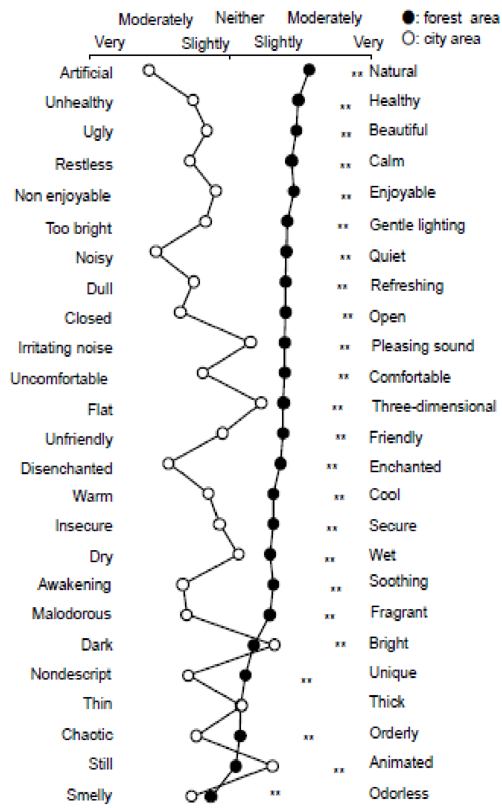

Figure 3. Results from the evaluations of the psychological responses to forest and urban environments reported using the SD method after the "Walking" phase of the study. Mean (N = 162–168), **: $p < 0.01$ by Steel-Dwass test.

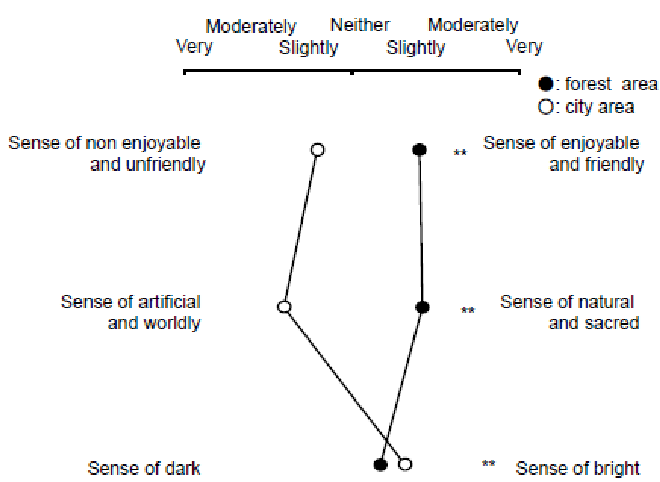

Figure 4. Results from principal component analysis based on factors derived from the results of the SD method reports of psychological responses to forest and urban environments. Mean (N = 162–168), **: $p < 0.01$ by Steel-Dwass test.

Table 2. Results of the principal component analysis

	Factor 1	Factor 2	Factor 3
Enjoyable vs.non enjoyable	0.86		
Friendly vs.unfriendly	0.80		
Comfortable vs.uncomfortable	0.76		
Calm vs. restless	0.73		
Refreshing vs. dull	0.70		
Secure vs. insecure	0.69		
Pleasing sound vs. irritating noise	0.67		
Beautiful vs. ugly	0.65		
Fragrant vs. malodorus	0.65		
Healthy vs.unhealthy	0.64		
Natural vs.artificial		0.77	
Enchanted vs. sidenchanted		0.75	
Quiet vs.noisy		0.70	
Gentle lighting vs. too bright		0.66	
Soothing vs. awakening		0.65	
Bright vs. dark			0.75
Variance (%)	27.6	24.1	4.4
Cumulative (%)	27.6	51.7	56.1
Cronbocks α	0.980	0.910	-

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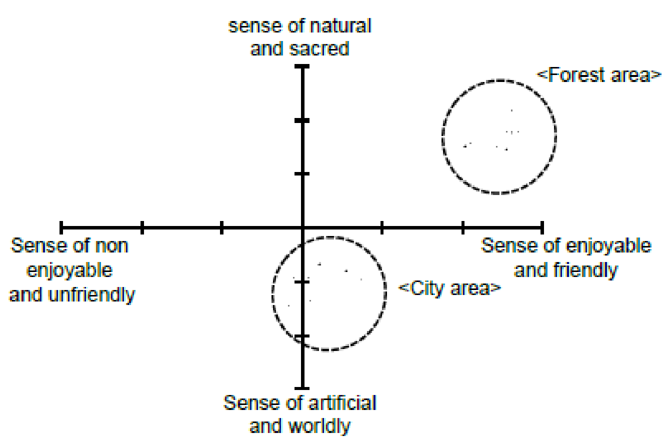

Figure 5. The spatial and sensory factors identified by the SD method as they relate to the 14 experimental areas. N = 14

The scores of the first and second principal components are plotted in Figure 5. The results indicate that forests are perceived as being "enjoyable and friendly" and "natural and enchanted" places whereas urban environments are perceived as being only slightly "enjoyable and friendly" and are not seen as "natural and enchanted" or "artificial and disenchanted" environments.

3.2. Results of Psychological Evaluations Measured by POMS

The Friedman test was used to compare the differences between the POMS results obtained from subjects who visited the forest and urban areas. Significant differences were found in the tension and anxiety (T-A), anger and hostility (A-H), fatigue (F), confusion (C), vigor (V) and total mood disturbance (TMD) subscales of POMS. The results of a post hoc Steel-Dwass test are shown in Figure 6.

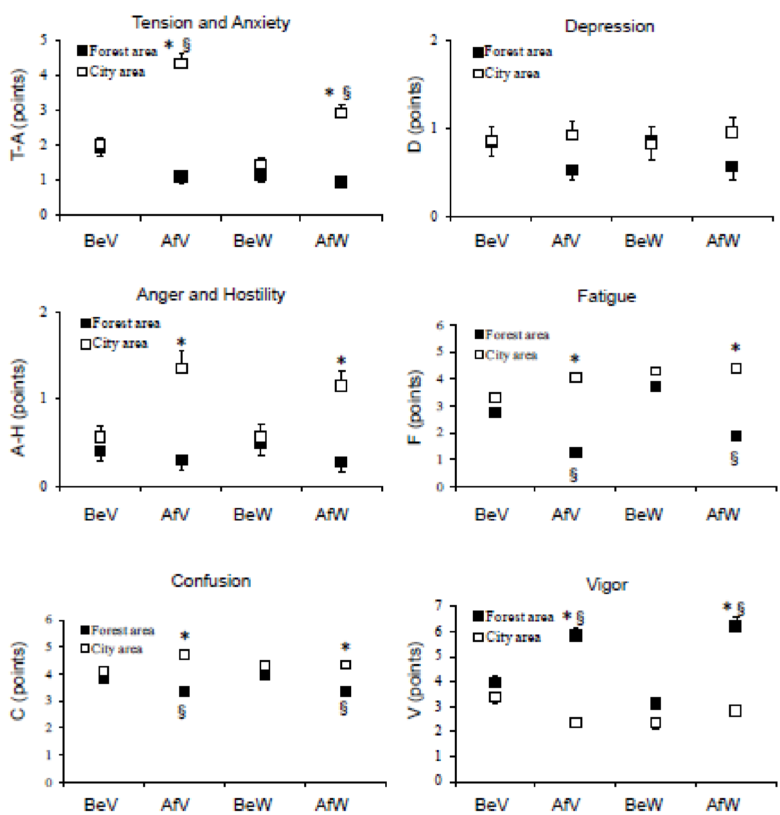

Figure 6. POMS subscale results showing the observed differences between forests and urban areas. Mean ± SD, N= 150-168, *: $p < 0.05$ by Steel-Dwass test of the differences between forests and urban areas, §: $p < 0.05$ by Steel-Dwass test of the differences between before and after "Viewing" phase as well as between before and after "Walking" phase. BeV: before "Viewing", AfV: after "Viewing", BeW: before "Walking", AfW: after "Walking".

For the tension and anxiety (T-A) subscale, significant differences between the forest and urban areas were observed in scores reported by subjects after the "Viewing" and "Walking" phases of the study. Moreover, significant differences were observed in the scores for tension and anxiety (T-A) before "Viewing" and after "Viewing" as well as before "Walking" and after "Walking" in the urban areas. This suggests that "Viewing" and "Walking" performed in urban areas can increase tension and anxiety. For the anger and hostility (A-H) subscales of POMS, significant differences between the results reported for the forest and urban areas were observed after "Viewing" as well as after "Walking" phases of the study. For the fatigue (F) and confusion (C) subscale, significant differences between the results reported for the forest and urban areas were observed for after "Viewing" and after "Walking" phases of the study. Scores for fatigue and confusion after "Viewing" and after "Walking" in forest areas were significantly lower than those reported before "Viewing" and before "Walking" in forest areas. Thus, performing "Viewing" and "Walking" activities in forest areas can reduce fatigue and confusion.

In contrast, for the vigor (V) subscale, scores were significantly higher after "Viewing" and after "Walking" in forests compared to that in urban areas. Moreover, significant differences were found between the before "Viewing" and after "Viewing" and between the before "Walking" and after "Walking," scores for vigor in the forest area. Thus, performing "Viewing" and "Walking" activities in forest areas can increase vigor.

Scores for the total mood disturbance (TMD) subscale of POMS (calculated by combining T-A + D + A-H + F + C – V) are shown in Figure 6. After performing both "Viewing" and "Walking" activities, the total mood disturbance (TMD) scores were significantly lower for the forest areas than for the urban areas. Moreover, significant differences between the before "Viewing" and after "Viewing" scores as well as between the before "Walking" and after "Walking" scores were observed. Therefore, performing "Viewing" and "Walking" activities in forest environments can decrease total mood disturbance (TMD), and performing "Viewing" and "Walking" activities in urban environments can increase total mood disturbance (TMD).

3.3. Results from Measurements of Physical Variables

Measurements of the physical variables were conducted for 2 days. The period of measurement was a typical summer season in Japan. The average air temperature in a forest area was 21.1 ± 4.1°C across the 14 locations. The highest temperature recorded was 28.7°C (site L) and the lowest was 14.1°C (site N). The average air temperature within an urban area was 26.6 ± 4.9°C across the 14 locations. The highest temperature recorded was 34.5°C (site E), and the lowest was 18.9°C (site N).

The average relative humidity in a forest area was 82.5 ± 11.6% across the 14 locations; the highest humidity recorded was 99.4% (site C) and the lowest 61.3% (site K). The average relative humidity in urban areas was 64.5 ± 13.7% across the 14 locations; the highest recorded relative humidity was 88.9% (site C) and the lowest 44.1% (site G).

The average radiant heat in a forest area was 22.9°C ± 4.8°C; the highest recorded reading was 30.2°C (site B) and the lowest 16.0°C (site N). In urban areas, the average radiant heat was 38.0 ± 6.8°C; the highest recorded radiant heat was 43.5°C (site H) and the lowest 30.5°C (site B).

Measurements of wind velocity in forest areas averaged 0.7 ± 0.5 m/s; the fastest air velocity recorded was 1.6 m/s (site B) and the slowest 0.1 m/s (sites E and J). In the urban areas, the average air velocity recorded was 2.1 ± 1.6 m/s; the fastest air velocity recorded was 3.8 m/s (site H) and the slowest was 0.8 m/s (site B). The average PMV value (which acts as an index of thermal comfort; ISO7730) was 0.2 (neutral) ± 0.8 in the forest areas; the highest value recorded was 1.8 (site L) and the lowest value was –1.0 (site M). The average PMV value in urban areas was 1.8 (warm) ± 1.2; the highest value recorded was 2.7 (site I) and the lowest value was 0.4 (site H). In forests, the average PPD value (which predicts the percentage of people who will be dissatisfied with the thermal conditions of their surroundings) was 24.5 ± 21.6%; the highest PPD value was 67.5% (site L) and the lowest value was 6.1% (site G). The average value of PPD was 63.9 ± 45.6% in urban areas; the highest value was 93.2 (site I) and the smallest value was 114% (site H). Air temperature, relative humidity, and radiant heat measurements over successive 1 hour periods between 10 h and 16 h in both forest and urban areas are shown in Figure 7. The air temperature in forest areas was significantly lower than that in urban areas at all times. The results from the relative humidity measurements indicate that the relative humidity in forest settings was significantly higher than that in urban settings. The radiant heat found in forest areas was also significantly lower than that in urban areas. Measurements of wind velocity, PMV, and PPD taken over successive 1 hour periods between 10 h and 16 h in both forest and urban areas are shown in Figure 7. In forest areas, wind velocity from 10 h to 11 h was significantly higher than that recorded in urban areas. From 10 h to 12 h, the PMV values recorded in forest areas were significantly lower than those recorded in urban areas; forest areas also had significantly lower PPD readings than those recorded in urban areas from 11 h to 16 h.

3.4. Relationship between Psychological Evaluations of Forest Settings and the Physical Variables that Characterize those Settings

The relationship between psychological responses and the physical variables of the environments is shown in Table 3. We used principal component analysis based on the first and second factor scores determined using the SD method and the TMD score from the POMS questionnaire administered after “Walking” as sources for the psychological responses. Air temperature, relative humidity, radiant heat, wind velocity, and PPD were used as physical variables pertaining to the environment. The p-value reported is that of the Spearman’s rank correlation coefficient; the r^2 value is the result of an ordinary correlation analysis. The results indicate that all psychological responses correlated significantly with all physical variables characterizing the environment. PPD is a predicted value of the percentage of people that are dissatisfied with the heat in the environment. PPD is calculated from PMV, which is an index that signifies the compound effect of six factors (temperature, humidity, wind velocity, radiant heat, amount of clothes, and metabolism level). The relationships between the PPD values and psychological responses are shown in Figure 8. The PPD value and the perception of the environment as being “enjoyable and friendly” showed significant negative correlation (r^2: 0.69); the PPD value also significantly negatively correlated with the perception of the environment as being “natural and enchanted” (r^2: 0.82). However, the PPD value showed a significant positive correlation with the TMD scores from the POMS questionnaire (r^2: 0.47).

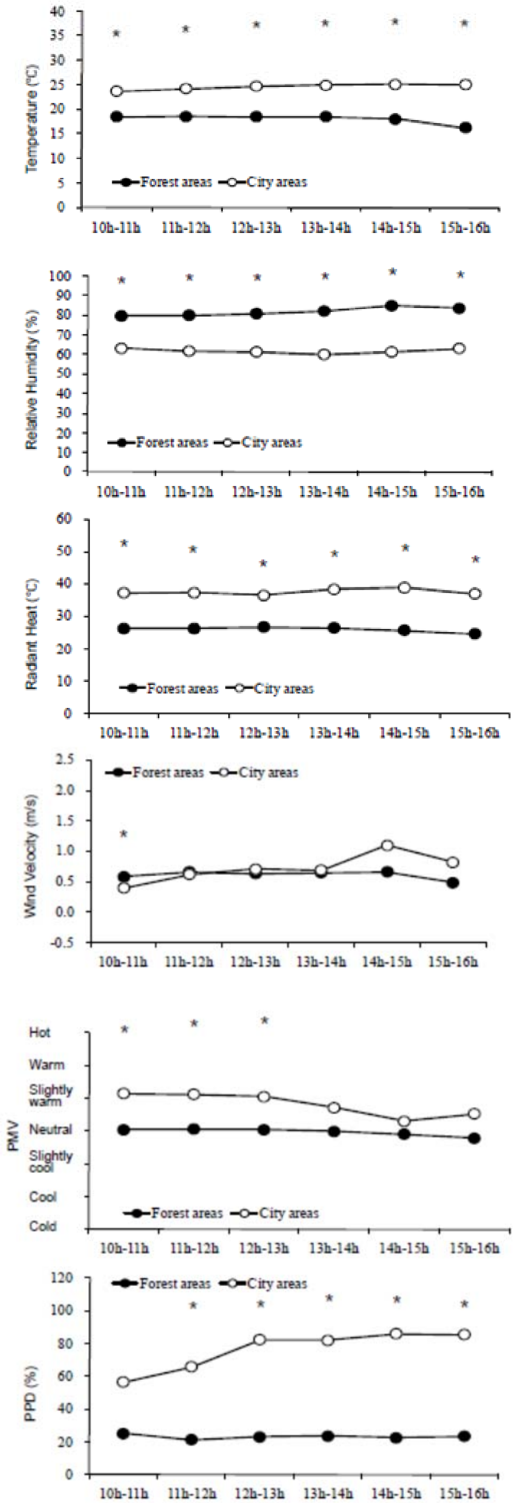

Figure 7. Physical variables measured in the forests and urban areas (continued.) Mean (N =162 in the forests, N=27 in the urban areas), *: $p < 0.05$ by non-paired t-test.

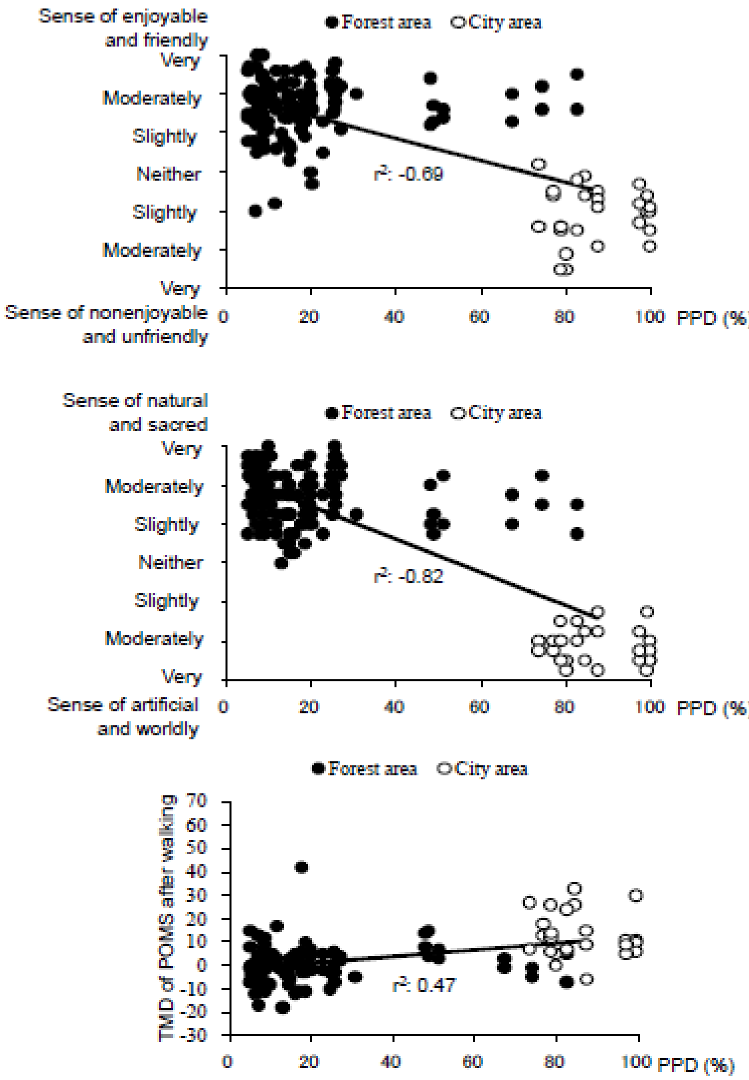

Figure 8. The relationship between PPD and psychological responses. N = 123–153

4. Discussions and Conclusions

In this study, we investigated psychological responses of humans to forest and urban environments by using field experiments. In addition, we attempted to identify the physical variables within the environments that were responsible for the observed improvements in psychological well-being.

Results of subjective responses using the SD method revealed that subjects reported higher positive emotions when they spent time in forests than when they spent time in urban areas. In particular, these results showed that forest settings were perceived as being very "enjoyable and friendly" and as very "natural and enchanted" places. Decreases in tension and anxiety (T-A), anger and hostility (A-H), fatigue (F), confusion (C), and total mood disturbance (TMD) increased vigor (V) were observed in forests by the POMS test, suggesting that forest settings are capable of enhancing positive mood states and reducing negative mood states.

The results of this study are consistent with those of previous studies documenting people's emotional responses to scenes of natural and urban landscapes (Hartig et al., 2003; Laumann et al., 2003; Morita et al., 2006; Ulrich et al., 1991). The rapid progress of technology has enabled application of certain physiological measurements to field experiments (Tsunetsugu et al., 2010). Hence, some studies have measured the physiological as well as psychological effects of forest environments on humans. The physiological studies have reported that forests can increase relaxation and positive emotions (Li et al., 2008; Lee et al., 2009; Park et al., 2009, 2010; Tsunetsugu et al., 2010). The results of the SD questionnaire also show that higher positive emotions were experienced in a forest setting, providing further evidence of the beneficial effects of forests on the well-being of people who live in urban areas.

Forests affect humans via their impact on each of the five human senses, including visual (scenery), olfactory (the smell of wood), auditory (sound of running streams or the rustle of leaves), and tactile (feeling the surfaces of leaves and trees) (Tsunetsugu et al., 2010). Previous studies have shown that viewing forest landscapes (such as those found in an urban park in Paris) can increase the incidence of positive emotions (feeling an increased sensation of comfort and feeling soothed), and can decrease blood pressure and prefrontal activity in the brain (Suda et al., 2001). Smelling forest scents (such as Japanese cedar chip) can also decrease blood pressure and prefrontal activity in the brain (Miyazaki et al., 1999). Thus, various studies have indicated that forests have a relaxing effect on humans. However, few field experiments have studied the relationship between the physical variables that characterize the forests and the relaxing effect that environment has on the study subjects. We therefore decided to focus our study on the physical variables that characterize the physical environment, such as air temperature, radiant heat, wind velocity and PPD.

We found that air temperature, radiant heat, wind velocity and PPD were all significantly lower in forests compared with urban areas. In addition, the relative humidity found in a forest setting was significantly higher than that found in an urban setting. PPD readings, which act as a typical index of the thermal conditions of an environment, were also significantly lower in forests than in urban areas. The average PPD value recorded in forests was 24.5 ± 21.6%, which means that 24.5 ± 21.6% of people would be dissatisfied with the thermal conditions in that environment. However, the average PPD value taken from the urban environment predicts that 63.9 ± 45.6% of people would be dissatisfied with the thermal conditions of their surroundings.

Thus, it appears that in terms of thermal conditions, a forest setting is more comfortable for people than an urban setting during the summer in Japan. During the summer, tropical forests may be more uncomfortable than urban environments due to the high temperature and humidity. However, temperate environments as the site of the study are more comfortable than urban environments. Our study results also indicate that thermal comfort is significantly correlated with reports of positive emotions, suggesting that thermal comfort is one of the reasons why people report more positive feelings in forests than in urban areas. Thus urban planners and landscape scientists must consider thermal environments when selecting a resting area, if a more comfortable environment is to be provided to the user of urban forests in the summer.

The limitation of this study is as follows:

(1) The effects of changes in seasons have not been considered in this paper. As the summer season has a high frequency in forest visits, the authors have set this season as the term of study and have accordingly conducted the study. (2) The relationship of the subjective sense of beauty or tranquility and physical variables has not been discussed in this study. It has only focused on the relationship of physical variables and mood states (tension and anxiety, depression, anger and hostility, vigor, confusion, fatigue) using POMS, and the relationship of physical variables and the impression of a space based on the SD method.

In summary, in forest areas, compared to urban areas (1) the incidence of positive emotions is significantly higher, (2) thermal conditions are more comfortable, and (3) positive emotions are correlated with thermal comfort.

Acknowledgments

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Section 3. Effects of the Forest Environment on Human Health

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Chapter 5

Effect of the Forest Environment on Physiological Relaxation Using the Results of Field Tests at 35 Sites throughout Japan

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Abstract

The purpose of this chapter is to clarify the physiological relaxation effect of a forest environment using field tests. We conducted field experiments in 35 forests across Japan. The subjects were twelve male university students at each location (420 in total; age range 21.8 ± 1.6 years). On the first day, 6 subjects were sent to a forest area, and the others to a city area. On the second day, each group was sent to the other area. The subjects walked (for 16 ± 5 min) around their assigned areas, and sat on chairs viewing the landscapes of their assigned areas (for 14 ± 2 min). Salivary cortisol, blood pressure, pulse rate, and heart rate variability (HRV) were used as 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. The R-R interval was also measured during the walking and viewing periods. The results show that forest environments promote lower concentrations of cortisol, lower pulse rate, lower blood pressure, greater parasympathetic nerve activity, and lower sympathetic nerve activity than city

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environments. These results will contribute to the development of a research field dedicated to forest-based therapy.

Keywords: Salivary cortisol, Blood pressure, Pulse rate, Heart rate variability, Field experiment

Introduction

Interest in environmental stress has been growing and evidence has shown that environmental stress can cause serious stress in people living in urban environments (Ulrich et al., 1991). A survey conducted by the Ministry of Health, Labour and Welfare of Japan (2000) reported that 54.2% of the respondents (32,000 Japanese individuals older than 12 years) rated their stress level as "very high" or "relatively high". In certain age groups, the proportion of individuals who stated excessive stress was as high as 60%–70%. Most people conceive that the natural environment can promote human health and several studies have shown the psychological effects of a forest environment on human health.

The concept of forest medicine was considered in the previous chapter; this means activities for relaxation and healthy lives by means of the forest environment. Today, *Shinrin-yoku* is a very famous nature therapy in Japan. The term *Shinrin-yoku* means taking in the forest atmosphere or forest bathing in Japanese. The term was suggested by the Japanese Ministry of Agriculture, Forestry and Fisheries in 1982. In Japan, interest in *Shinrin-yoku*'s ability to provide relaxation and reduce stress is increasing nowadays (Park et al., 2007). *Shinrin-yoku* is popularly accepted as an easily available way to get in touch with the natural world in order to lower high stress. In Europe, Kneipp therapy in Germany is the most well-known case of the therapeutic use of the natural environment for individuals in urban life. However although the concept of *Shinrin-yoku* is becoming wide-spread, the effects of *Shinrin-yoku* require more scientific evidence.

As social interest in *Shinrin-yoku* spreads and the requirements for experimental evidence are increasing, the Forestry and Forest Products Research Institute (FFPRI) and Chiba University are accumulating scientific data on *Shinrin-yoku* in Japan. In Europe, similar trials were done in COST Action E39 on forest and human health from 2004 to 2008 (Editorial of Urban Forest and Urban Greening, 2007). At the global level, the International Union of Forest Research Organizations (IUFRO) launched a new task force on forests and human health in Finland in 2007. The task force team aimed to promote cross-disciplinary dialogue between the different researchers in this field, especially forestry and health professionals.

Also, the Japanese Society of Forest Medicine was established in 2007 in the Japanese Society for Hygiene. The society promotes research in the field of forest medicine, including the effect of forest bathing trips and the therapeutic effects of forests on human health. Several field studies on the physiological effects of forest environments have been carried out throughout Japan (Lee et al., 2009, Li et al., 2007, Li et al., 2008a, Li et al., 2008b, Park et al., 2007, Park et al., 2008, Park et al., 2009, Park et al., 20010, Tsunetsugu et al., 2007, Tsunetsugu et al., 2010).

In this chapter, we will review the field studies regarding forest environments' effects on humans and selected studies on the physiological effects of *Shinrin-yoku*. All of them are focused on the physiological effects of *Shinrin-yoku*. The review will help to understand the trend of forest therapy studies in Japan today.

Table 1. Measured physiological parameters

Autonomic nervous Activity	Pulse rate, Systolic blood pressure,
	Heart rate variability (HRV) HF component (parasympathetic nervous activity) LF/HF or LF/(LF+HF) (sympathetic nervous activity)
Endocrine system Activity	Salivary cortisol concentration

Subjects and Sites

Physiological experiments were conducted in 35 areas from 2005 to 2006 in Japan. In each experiment, 12 normal male university students (420 in total; age range 21.8 ± 1.6 years) participated as subjects; none reported previous physical or psychiatric disorders. The experiments were performed under the regulations of the Institutional Ethical Committee of the Forestry and Forest Products Research Institute and Chiba University in Japan. On the day before the experiments, subjects were carefully informed of the aims and procedures of the experiments and they assented to them.

Physiological Measurements

Five physiological factors were analyzed in the study (Table 1). In order to measure salivary cortisol concentration, saliva was collected by subjects' holding 2 pieces of absorbent cotton in the mouth for 2 minutes. A saliva collection tube (No. 51.1534, Sarstedt, Numbrecht, Germany) was used. Immediately after collection, the tubes were sealed with tape and immediately stored and frozen for cortisol concentration analysis (SRL, Inc., Japan). Heart rate variability (HRV) was measured and it was analyzed for the periods between consecutive R waves on an electrocardiogram (R-R intervals) measured by a portable electrocardiograph (AC-301A, GMS Corporation). The power levels of the high-frequency (HF; 0.15–0.4 Hz) and low-frequency components (LF; 0.04–0.15 Hz) were calculated every minute (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology 1996) by the maximum entropy method (Mem-Calc, GMS Ltd.). The HF power is assumed to reflect parasympathetic nervous activity (Cacioppo, 1994). The power ratios LF/HF and LF/(LF+HF) were measured (Weise, 1989) and these are thought to reflect sympathetic nervous activity. Systolic blood pressure, diastolic blood pressure, and pulse rate were measured with oscillometric methods (HEM1000, Omron, Japan) on the right upper arm by a digital blood pressure monitor.

Experimental Design

On the day before the first day of experiments, orientation was given to the subjects. They visited and previewed the experimental sites in the forest and city. Measurements of all physiological indexes were conducted at the accommodation facility. Identical and separate rooms were prepared for each subject's lodging place and identical meals were served during the experimental days to control the background environmental conditions. The subjects were randomly divided into 2 groups of 6. On the first day of the experiments, one group was sent to a forest site, and the other to a city site. On the second day, they were sent to the other site as a cross-check. The first measurement was taken in the early morning at the lodging place before breakfast. After the first measurement, the subjects were sent to each experimental site. It took almost the same time to reach the two sites from the lodging place. As shown in Figure 1, as soon as they reached the site, the subjects were seated on chairs and viewed the landscape (for 14 ± 2 min). Next, they walked around the given site (for 16 ± 5 min). The second and third measurements were taken before and after viewing. The fourth and fifth were taken before and after walking. The measurements were taken for 1 person at each time point. The R-R interval was measured continuously during the viewing and walking experiments. The HRV was calculated once a minute with the R-R interval data. The exercise loads during walking exercise were estimated by an activity monitor (AC-301A, GMS, Japan); there was no difference in exercise load between the forest and city sites. During experiments, the consumption of alcohol and tobacco was prohibited and caffeine consumption was controlled. For a comparison of each physiological factor between the forest and urban settings, a t-test was used. Statistical analysis of physiological data was processed using EXCEL 2007 (Microsoft Inc.). A p value of <0.05 was considered significant.

Figure 1. Forest viewing and walking.

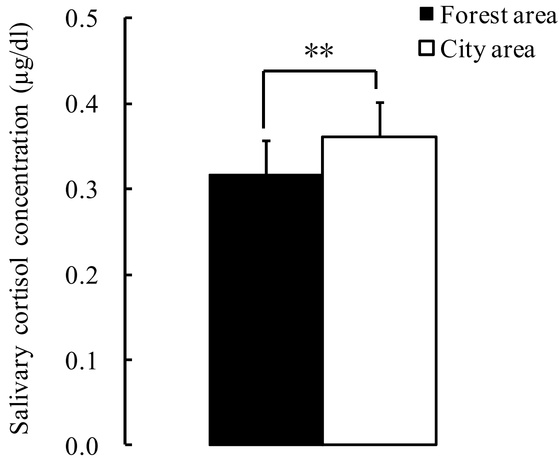
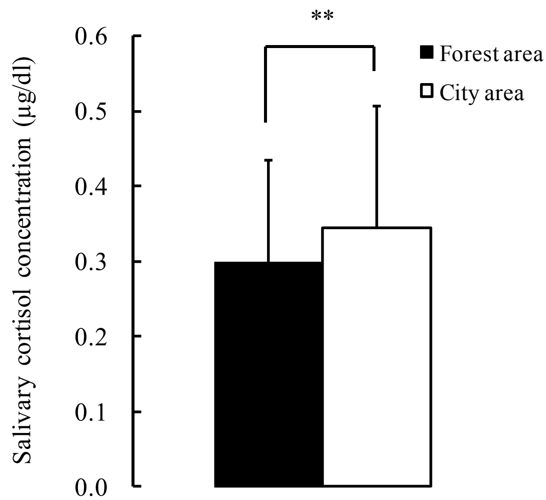


Figure 2. Changes in salivary cortisol concentration after forest and city area viewing (N=385; Mean ± SD; ** $p < 0.01$ by t-test).

Results and Discussion

Figures 2 and 3 show the average cortisol concentration in the saliva. Salivary cortisol of the subjects was significantly lower in the forest area (12.4% decrease after viewing; 15.8% decrease after walking) than that in the city area. Figures 4 and 5 show that the average pulse rate was significantly lower in the forest area (5.8% decrease after viewing; 3.9% decrease after walking), while Figures 6 and 7 show that the average systolic blood pressure was significantly lower in the forest setting (1.4% decrease after viewing; 1.9% decrease after walking). The average power of the HF components of the HRV increase when we feel relaxed. Figures 8 and 9 show that the average power of the HF components of the HRV was significantly enhanced in the forest (55.0% enhancement after viewing; 102.7% enhancement after walking). This is considered to be related to parasympathetic nervous activity. The average LF/(LF+HF) ratio of HRV increases when we feel stress. Figures 10 and 11 show that the average LF/(LF+HF) ratio of the HRV decreased when the subjects were walking in or viewing a forest (7.0% decrease after viewing; 4.4% decrease after walking). This is thought to be related to sympathetic nervous activity. The results show that viewing forest landscapes and walking in forest settings lowered concentrations of cortisol, lowered pulse rate, lowered blood pressure, enhanced HF components of HRV, and lowered LF/HF. These result strongly support Hartig et al.'s (2003) finding that walking in a nature reserve initially fosters blood pressure changes that indicate greater stress reduction than walking in a city. The endocrine stress system comprises 2 broad components. They are considerable central anatomic interconnections, namely, the sympathetic adrenal-medullary (SAM) axis and the hypothalamic-pituitary-adrenal (HPA) axis (Dinan, 2004). The SAM axis is involved in immediate sympathetic activation which prepares an individual to deal with a stressor. This results in such changes as increased heart rate (HR) and blood pressure (BP) (Vente et al., 2003).



(*Source*: Park et al. 2010).

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Figure 3. Changes in salivary cortisol concentration after forest and city area walking (N=74; Mean ± SD; ** $p < 0.01$ by *t*-test).

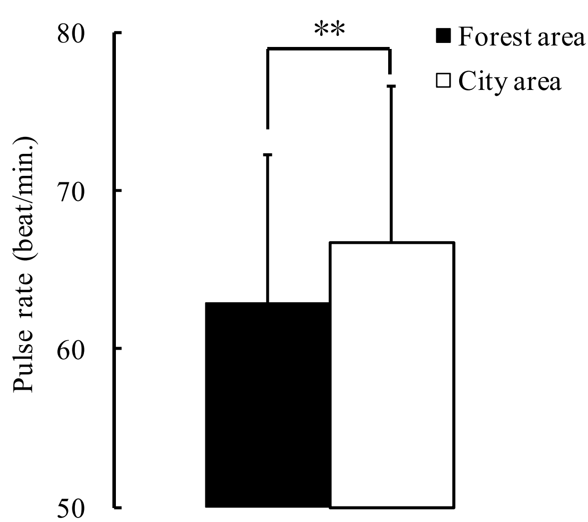

Figure 4. Changes in pulse rate after forest and city area viewing (N=398; Mean ± SD; ** $p < 0.01$ by *t*-test).

Cortisol is released in response to stress by the HPA axis (Seplaki, 2004). While subjects were watching forest landscapes or walking around a forest, their pulse rate, blood pressure, and cortisol concentration decreased. This suggests that *Shinrin-yoku* affects both the main components of the endocrine stress system. The studies of Li et al. (2007, 2008a, 2008b) already reported that forest surroundings could aid in the recovery of the human immune system, as determined from the perspective of NK (natural killer) activity.

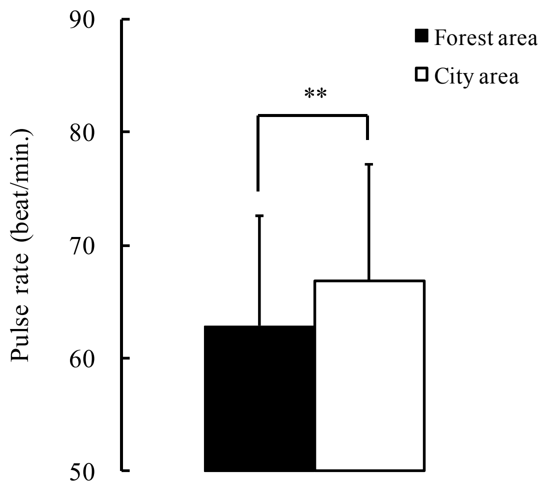

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Figure 5. Changes in pulse rate after forest and city area walking (N=75; Mean ± SD; ** $p < 0.01$ by *t*-test).

All the indices were generally in excellent agreement with each other, and they imply that the forest environment has relaxing and stress-relieving effects on humans. The results with the widely held belief that forest surroundings aid physical relaxation. Human beings have lived in the natural environment for most of the last 5 million years (Miyazaki, 2002). Therefore, their physiological functions are adapted to natural settings. This is one reason the natural environment relaxes the human body and mind. The results of the physiological experiments can explain the relationship between the forest environment and the relaxation effects in humans.

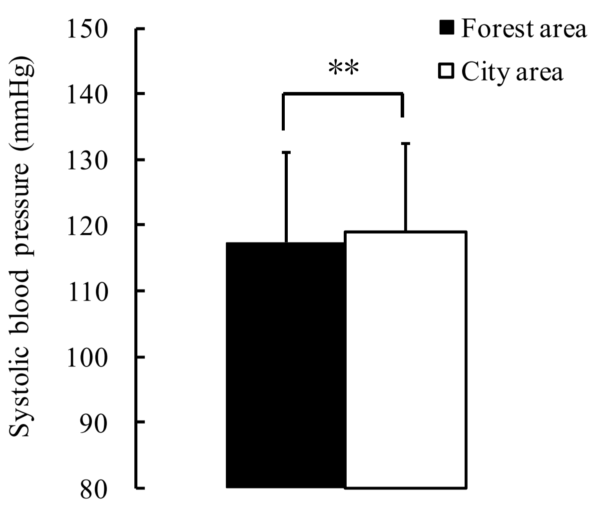
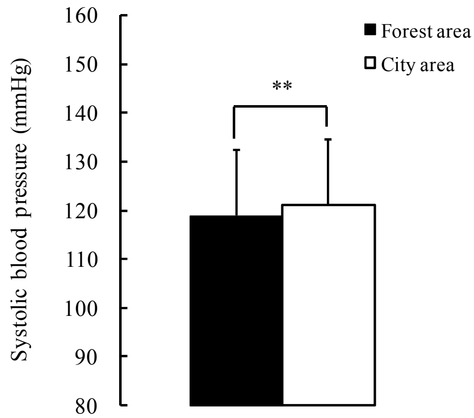


Figure 6. Changes in systolic blood pressure after forest and city area viewing (N=397; Mean ± SD; ** $p < 0.01$ by *t*-test).



(Source: Park et al., 2010)

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Figure 7. Changes in systolic blood pressure after forest and city area walking (N=75; Mean ± SD; * $p < 0.05$ by *t*-test).

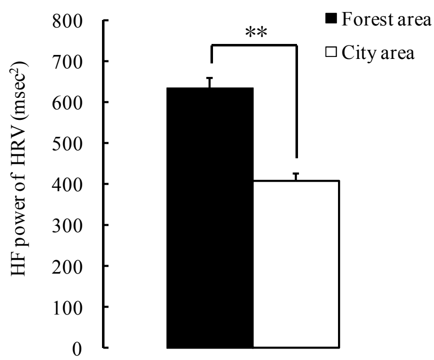

Figure 8. Changes in HF power of HRV during forest and city area viewing (N=387; Mean ± SE; ** $p < 0.01$ by *t*-test).

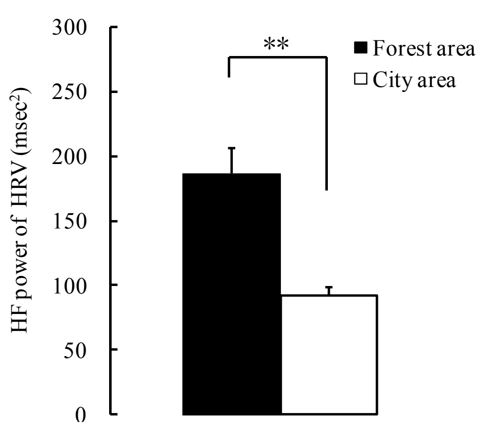

Figure 9. Changes in HF power of HRV during forest and city area walking (N=322; Mean ± SE; ** $p < 0.01$ by *t*-test).

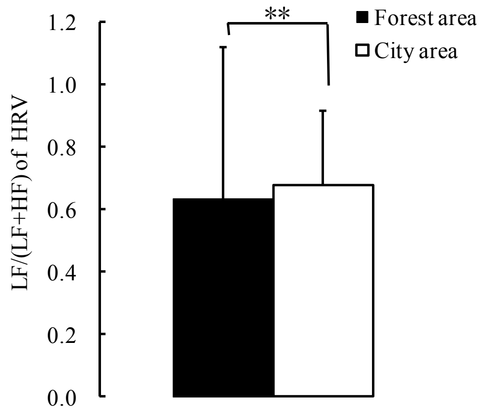

Figure 10. Changes in LF/(LF+HF) of HRV during forest and city area viewing (N=387; Mean ± SE; ** $p < 0.01$ by *t*-test).

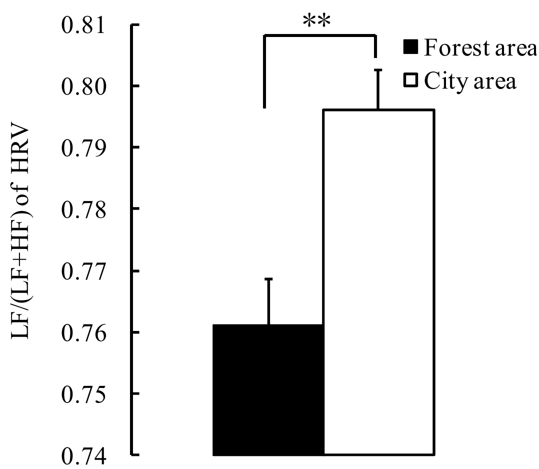

Figure 11. Changes in LF/(LF+HF) of HRV during forest and city area walking (N=322; Mean ± SE; ** $p < 0.01$ by *t*-test).

Conclusion

Scientific evidence of the therapeutic effects of forests is being accumulated. This will help *Shinrin-yoku* to be better understood and practically applied by humans in their daily live to improve health and relax. The accumulation of data should be continued and hopefully, the types of forest environment suitable for *Shinrin-yoku* will increase.

Shinrin-yoku programs need to be customized for individuals. Research on the effects of *Shinrin-yoku* on individuals of different physical strength, personal preferences, physiological characteristics, personalities and ages will provide primary support for customized *Shinrin-yoku* programs.

This review focused on research in Japan, but an increasing number of studies are being conducted around the world. International cooperation is needed to clarify the effects of forest environments on human health in the future. It is expected that this accumulation of studies will contribute to reductions in medical costs and revitalization of forest areas.

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Chapter 6

Effect of Forest Environments on Human Immune Function

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Abstract

Since 2004, a serial studies have been conducted to investigate the effect of forest environments on human immune function in both males and females in Japan. This review focuses on effects of forest bathing trips on human immune function. Subjects participated in a three-day/two-night trip or a day trip to a forest area, and blood and urine were sampled on days 2, 3, 7, and 30 during or after the trips. Natural killer (NK) activity and the numbers of NK, NKT and granulysin (GRN), perforin, and granzymes A/B (GrA/B)-expressing lymphocytes in blood, the levels of IL-6, IL-10, IL-12 and IL-18, TNF-alpha in plasma and concentration of urinary adrenaline were measured. The same measurements were made before the trips on a normal working day as a control. The NK activity and the numbers of NK, NKT, GRN, perforin, and GrA/B-expressing cells on forest bathing days were significantly higher than those on the control days, whereas the concentration of urinary adrenaline on forest bathing days were significantly lower than that on the control days in both males and females. The increased NK activity lasted for more than 30 days after the trip. This suggests that if people take a forest bathing trip once a month, they may be able to maintain a higher level of NK activity. In contrast, a city trip did not increase NK activity, the numbers of NK cells, or the level of intracellular GRN, perforin, and GrA/B. These findings indicate that forest bathing trips increased NK activity, which was mediated by increases in the number of NK cells and the levels of intracellular GRN, perforin, and GrA/B. Phytoncides released from trees and the decreased production of stress hormones may partially contribute to the increased NK activity. Because NK cells can kill tumor cells by releasing anti-cancer proteins, and visiting forests increases NK activity and the amount of anti-cancer proteins; therefore, the above findings suggest that visiting forests may have a preventive effect on cancer generation and progression.

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Keywords: Adrenaline, Forest environment, Granulysin, Granzyme, NK activity, Perforin, Phytoncides

Introduction

Forest environments have been enjoyed by humans for ages because of the quiet atmosphere, beautiful scenery, mild climate, and clean fresh air found in forests. A forest bathing trip is a short, leisurely trip to visit a forest park, called "Shinrinyoku" in Japanese, which is similar to natural aromatherapy. A forest bathing trip involves visiting a forest park for relaxation and recreation while breathing in volatile organic substances, called phytoncides derived from trees, such as α-pinene and limonene [1-7]. Incorporating forest bathing trips into a healthy lifestyle was first proposed in 1982 by the Forest Agency of Japan [7]. It has now become a well-recognized relaxation and/or stress management activity in Japan [2-4, 6-7]. Forest bathing trips significantly increased the score for vigor and decreased the scores for anxiety, depression, anger, confusion, and fatigue as investigated by the Profile of Mood States (POMS) test [2, 4, 6-7]. Forest bathing trips also can reduce blood pressure, reduce the concentration of cortisol in saliva, reduce prefrontal cerebral activity, and stabilize autonomic nervous activity in humans [8]. Because forests occupy 67% of the land in Japan, forest bathing is easily accessible [7, 9]. Moreover, forest bathing is possible in similar forest environments throughout the world. It is well known that the immune system including natural killer (NK) cells plays an important role on the defense against bacteria, viruses and tumors. It is also well known that stress inhibits immune function [10]. People with higher NK activity showed a lower incidence of cancers, whereas people with lower NK activity showed a higher incidence of cancers [11], indicating the importance of NK cell function on cancer prevention. In addition, patients with an advanced performance status had significantly fewer granulysin-positive NK cells than healthy controls; impaired expression of granulysin by NK cells correlates with progression of cancer, and determination of granulysin expression might prove informative for assessing the immunological condition of cancer patients, indicating the importance of granulysin on cancer progression [12]. Empirically, forest environments may reduce stress. Therefore, we speculate that forest environments may have beneficial effects on immune function by reducing stress. However, there have been no reports to date investigating the effect of forest environments on human immune function except for the studies conducted by authors.

Effect of Forest Environments on Human NK Activity in Male Subjects

Based on the background mentioned above, since 2005 a series of investigations to study the effect of forest bathing trips on human immune function have been conducted in Japan [2-4, 6-7]. In the first study [2], 12 healthy male subjects, aged 37-55 years, were selected from three large companies in Tokyo, Japan. The information of the subjects gathered from a self-administered questionnaire, including age and lifestyle habits, has been reported previously [13]. None of the subjects had any signs or symptoms of infectious diseases, used drugs that might affect immunological analysis, or were taking any medication at the time of the study. The subjects participated in a three-day/two-night trip to forest areas at Iiyama in Nagano prefecture located in northwest Japan in early September, 2005. On day 1, the subjects walked about 2.5 km. This level of exertion was selected because it closely resembles the average amount of physical activity in a normal working day. This walk was conducted in the forest park during the afternoon. Participants were allowed to rest anywhere and anytime they chose. On day 2, they walked about 2.5 km over two hours both in the morning and afternoon, respectively, in two different forest parks; and on day 3, the subjects finished the trip and returned to Tokyo after blood was drawn and a questionnaire survey was completed. The forests included Japanese cedar (Cryptomeria), Japanese beech, and Japanese oak. Blood was sampled on the second and third days. White blood cell (WBC) counts, NK activity, numbers of NK and T cells, and numbers of granulysin (GRN), perforin, and granzymes A and B (GrA/B)-expressing lymphocytes were measured in the blood samples. The same measurements were made before the trips on a normal working day as a control. Blood was sampled at 8:00 am on all occasions. To control for the effect of alcohol on NK activity, the subjects did not consume alcohol for 2 days before blood was drawn. Phytoncide concentrations in forest air samples were also measured. Walk in forests significantly increased human NK activity (Figure 1A) and the numbers of NK cells (Figure 1B). It has been reported that NK cells kill tumor or virus-infected cells by the release of perforin, granzymes, and GRN via the granule exocytosis pathway [14-18]. In order to explore the mechanism of enhancement of NK activity induced by the forest environments, the effect of forest environments on the intracellular levels of perforin, GRN, and GrA/B in peripheral blood lymphocytes (PBL) were investigated, and it was found that the forest environments also significantly increased the numbers of intracellular perforin-, GRN-, and GrA/B-expressing lymphocytes (Figure 2).

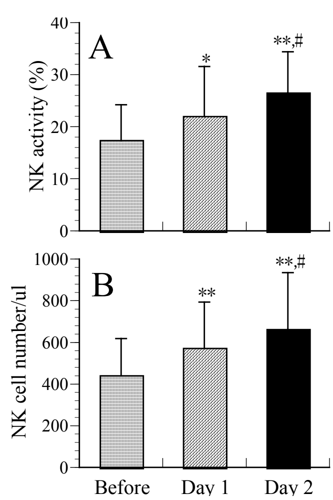

Figure 1. Effect of a forest bathing trip on NK activity (A) and the number of NK cells (B). The columns labeled “Before” indicate the data determined before the trip, the columns labeled “Day 1” indicate the data determined after the first day of the trip, the columns labeled “Day 2” indicate the data determined after the second day of the trip. Data are presented as the mean+SD (n=12). *: p<0.05, **: p<0.01, significantly different from before the trip, #: p<0.05 significantly different from day 1 by paired t-test. Cited from Li et al. Int J Immunopathol Pharmacol. 2007;20:3-8 with permission from Biolife.

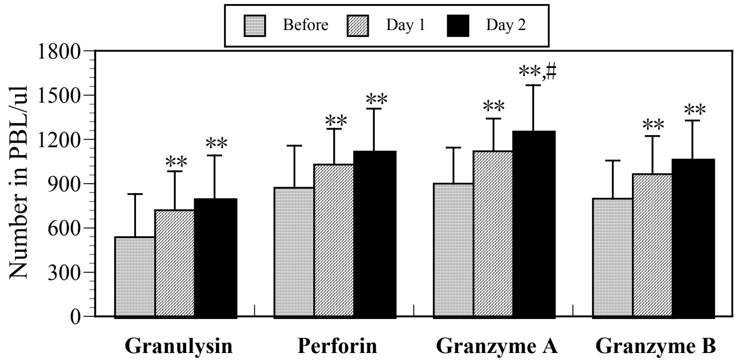

Figure 2. Effect of a forest bathing trip on the numbers of GRN, perforin, GrA/B-expressing cells in PBL. Data are presented as the mean+SD (n=12). **: $p<0.01$, significantly different from before the trip, #: $p<0.05$ significantly different from day 1 by paired t-test. Cited from Li et al. Int J Immunopathol Pharmacol. 2007;20:3-8 with permission from Biolife.

Taken together, these findings indicate that forest environments can increase NK activity, and that this effect might be at least partially mediated by increasing the number of NK cells and by the induction of intracellular perforin, GRN, and GrA/B [2].

Does a Trip to Places without Forest (A City Tourist Visit) also Increase NK Activity?

A question remain to be resolved: will a trip to places without forest (a city tourist visit) also increase NK activity? Thus, to determine whether taking a trip (city tourist visit) can also affect NK activity, eleven healthy male subjects, aged 35-56 years, experienced a three-day/two-night trip to Nagoya city in mid-May, 2006 [3]. Information on the subjects was gathered from a self-administered questionnaire, including age and lifestyle habits as described previously [13].

On the first day, the subjects walked for two hours in the afternoon along a tourist route through a historic district in Nagoya, and then stayed at a hotel also in Nagoya. On the second day, the subjects walked for 2 hours around the Nagoya Baseball Dome in the morning and 2 hours around/in Nagoya Airport in nearby Nagoya city in the afternoon. There are some areas with trees in Nagoya city, but there are almost no trees in the areas visited.

The class of hotel was the same and the lifestyle of the subjects during the stays in the hotels was the same for the city and the forest trips. The walking courses in the trip were 2.5 km, which was the same as the previous study [2]. Blood was sampled at 8:00 am on the second and third days after the trip, and three days prior to the trip as a control. WBC counts, NK activity, proportions of NK and T cells, and GRN-, perforin-, and GrA/B-expressing cells in PBL were measured. Adrenaline concentration in urine was also measured. As shown in Figure 3, the city tourist visit did not increase human NK activity, numbers of NK cells, or the expression of the selected intracellular perforin, GRN, and GrA/B, indicating that increased NK activity during forest bathing trip was not due to the trip itself, but due to forest environments [3].

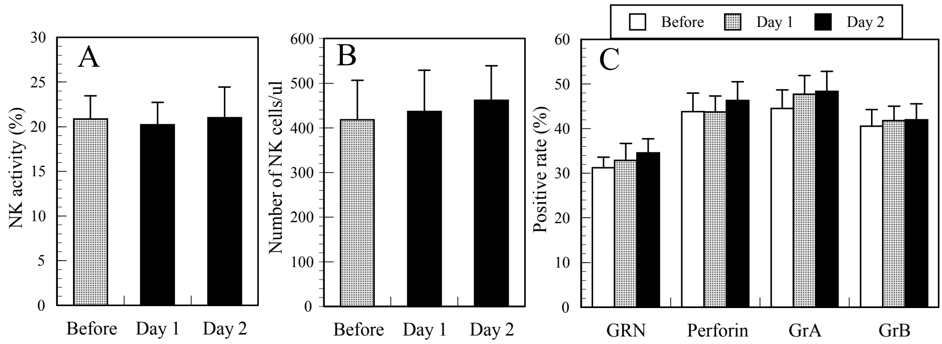

Figure 3. Effect of a city tourist visit on NK activity (A), the number of NK cells (B), and the positive rates of GRN, perforin, and GrA/B-expressing cells in PBL. Data are presented as the mean+SE (n=11). Cited from Li et al. Int J Immunopathol Pharmacol. 2008;21:117-128 [3].

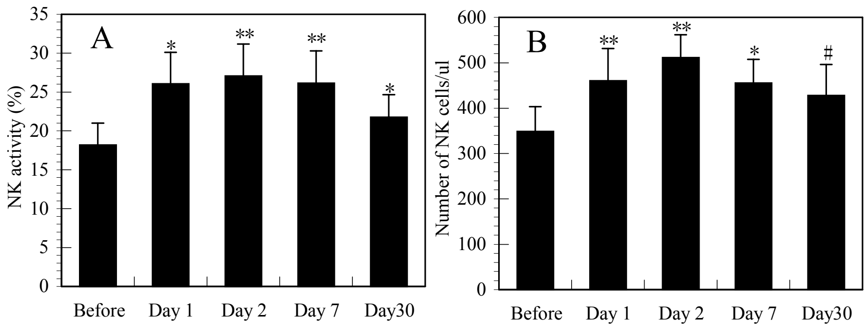

Figure 4. Effect of a forest bathing trip on NK activity (A) and the number of NK cells (B). Data are presented as the mean+SE (n=12). *: p<0.05, **: p<0.01, #: p=0.054 significantly different from before the trip by paired t-test. Cited from Li et al. Int J Immunopathol Pharmacol. 2008;21:117-128 with permission from Biolife.

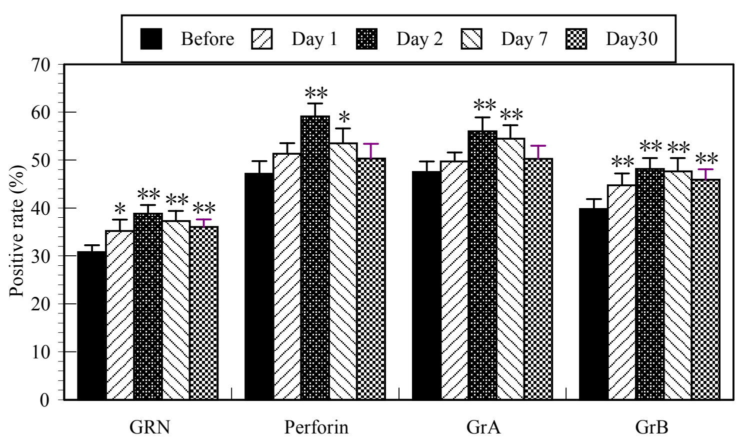

Figure 5. Effect of a forest bathing trip on the positive rates of GRN, perforin, and GrA/B-expressing cells in PBL. Data are presented as the mean+SE (n=12). *: p<0.05, **: p<0.01, significantly different from before the trip by paired t-test. Cited from Li et al. Int J Immunopathol Pharmacol. 2008;21:117-128 with permission from Biolife.

How Long Does the Increased NK Activity Last After a Forest Park Visiting?

Another question remain to be resolved: how long does the increased NK activity last after a forest bathing trip? Thus, an investigation was conducted to address this question [3]. Twelve healthy male subjects, aged 35-56 years, were selected from four large companies in Tokyo, Japan. Information on the subjects was gathered from a self-administered questionnaire, including age and lifestyle habits as described previously [13]. The subjects experienced a three-day/two-night trip to three different *Chamaecyparis obtuse* (Japanese cypress, Hinoki in Japanese) forest parks around Agematsu town in Nagano prefecture located in northwest Japan in early September, 2006. The schedule of the forest bathing trip was similar to that described previously [2].

Blood was sampled at 8:00 am on the second and third days, on days 7 and 30 after the forest bathing trip, and three days prior to the trip as a control. WBC counts, NK activity, proportions of NK and T cells, and GRN-, perforin-, and GrA/B-expressing cells in PBL were measured. Spot urine was sampled at 7:00 am on the second and third days, on days 7 and 30 after the forest bathing trip, and three days prior to the trip as a control. Adrenaline concentration in urine was also measured. The forest bathing trip significantly increased human NK activity (Figure 4A), the numbers of NK cells (Figure 4B), and the percentages of GRN-, perforin-, and GrA/B-expressing cells in PBL (Figure 5), which confirmed the previous findings [2]. The increased NK activity, number of $CD16^{+}$ NK cells, and percentages of GRN-, perforin-, and GrA/B-expressing cells lasted more than 7 days and even for 30 days in the cases of NK activity, the number of NK cells, and GRN- and GrB-expressing cells. These findings indicate that a forest bathing trip increased NK activity, the number of NK cells, and the levels of intracellular perforin, GRN, and GrA/B, and that these effects lasted for at least seven days after the trip [3]. The important finding is that visiting a forest, rather than a city, increases NK activity and the intracellular levels of perforin, GRN, and GrA/B.

A Day Trip to A Forest Park also Increased Human NK Activity

Although a three-day/two-night trip to a forest enhanced human NK activity, the number of NK cells, and intracellular anti-cancer proteins in lymphocytes, it is not clear whether a day trip to a forest park also increases human NK activity. Recently, we found that a day trip to a forest park also increased human NK activity and the expression of anti-cancer proteins in male subjects [6].

In this study, twelve healthy male subjects, aged 35-53 years, were selected after giving informed consent. The subjects experienced a day trip to a forest park in the suburbs of Tokyo. They walked for two hours in the morning and afternoon, respectively, in the forest park on Sunday. Blood and urine were sampled the following morning and again seven days after the trip. The NK activity, numbers of NK and T cells, and GRN, perforin, and GrA/B-expressing lymphocytes, the concentration of cortisol in blood samples, and the concentration of adrenaline in urine were measured. Similar measurements were made before the trip on a weekend day as the control. Phytoncide concentrations in the forest were measured.

The day trip to the forest park significantly increased NK activity (Figure 6A) and the numbers of NK (Figure 6BC), perforin, GRN, and GrA/B-expressing cells (Figure 7) while significantly decreasing the concentrations of cortisol in the blood and adrenaline in urine. The increased NK activity lasted for seven days after the trip. Phytoncides, such as isoprene, α-pinene and β-pinene, were detected in the forest air. These findings indicate that the day trip to the forest park also increased the NK activity, number of NK cells, and levels of intracellular anti-cancer proteins, and that this effect lasted for at least seven days after the trip.

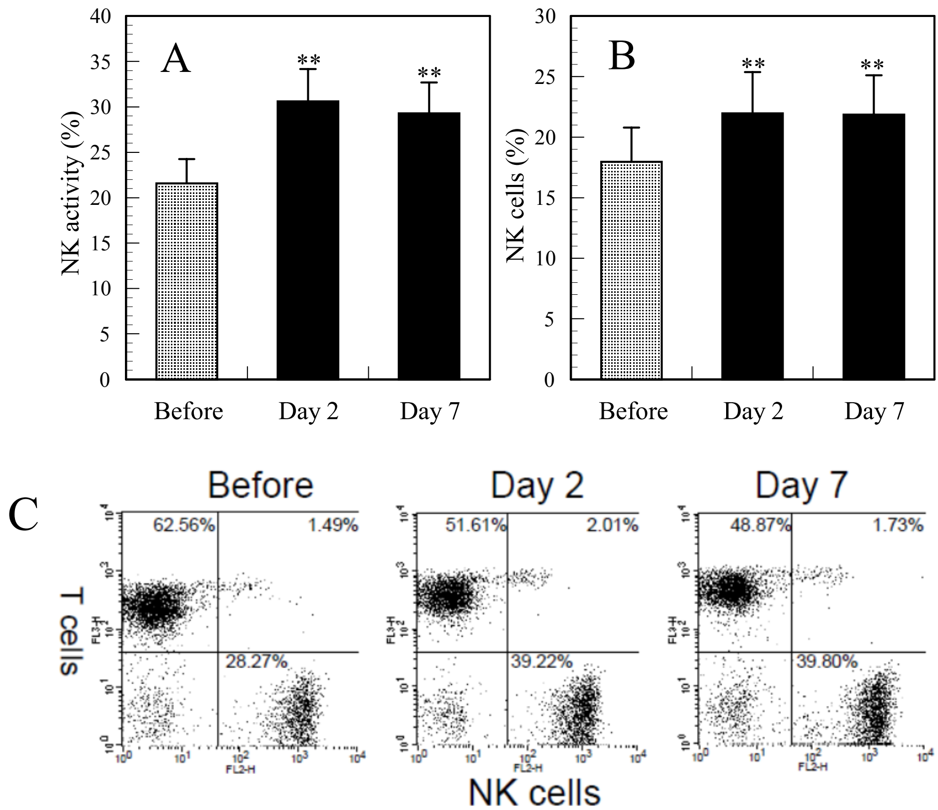

Figure 6. Effect of a day trip to a forest park on human NK activity (A) and the number of NK cells (B, C). C: Dot plots of PE-CD16 (NK cells)/PerCP-Cy5.5-CD3 (T cells) in PBLs of a subject before the trip (left), on day 2 (middle), and day 7 (right) after the trip. The horizontal axis shows the intensity of fluorescence of PE-CD16 (NK cells), while the vertical axis shows the intensity of fluorescence of PerCP-Cy5.5-CD3 (T cells). Percentages in quadrants 2 and 3 show $CD16^+$/ $CD3^+$ and $CD16^+$/ $CD3^-$ cells, respectively. Data are presented as the mean+SE (n=12). Two-way ANOVA with no-repeated measures indicated that the forest bathing trip and variability between individuals significantly affected NK activity (all $p<0.01$). **: $p<0.01$, significantly different from before the trip by the paired t-test. Cited from Li et al. J Biol Regul Homeost Agents. 2010; 24: 157-165 with permission from Biolife.

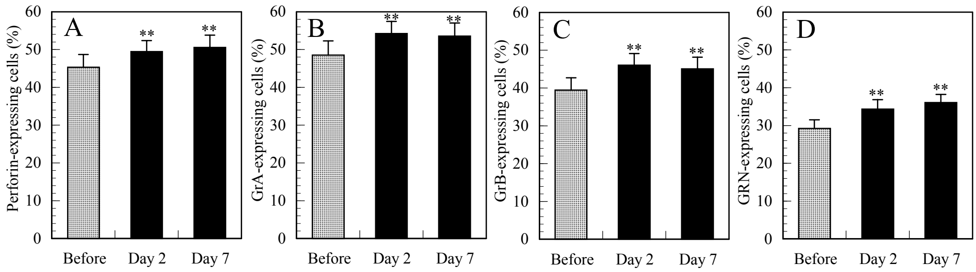

Figure 7. Effect of a day trip to a forest park on the positive rate of perforin (A), and GrA (B), GrB (C) and GRN-expressing cells (D) in PBL. Data are presented as the mean+SE (n=12). Two-way ANOVA with no-repeated measures indicated that the forest bathing trip and variability between individuals significantly affected NK activity (all $p<0.01$). **: $p<0.01$, significantly different from before the trip by the paired t-test. Cited from Li et al. J Biol Regul Homeost Agents. 2010; 24: 157-165 with permission from Biolife.

Effect of Forest Environments on Human NK Activity in Female Subjects

Although it has been demonstrated that forest bathing trips enhance human NK activity in male subjects, it still remained to be resolved whether or not forest bathing trips also increase NK activity in female subjects. It has been reported that menstrual cycle significantly affects NK activity [19]; therefore, the influence of menstrual cycle on NK activity should be controlled for in experiments with female subjects.

In this study [4], thirteen healthy nurses, aged 25-43 years, professional career 4-18 years, were selected with informed consent. None of the subjects had any signs or symptoms of infectious disease, used drugs that might affect immunological analysis, or were taking any medication at the time of the study. The subjects experienced a three-day/two-night trip to forest fields around Shinano town in Nagano prefecture located in northwest Japan in early September of 2007. The schedule of the forest bathing trip and blood/urine sampling was similar to that described previously [2-3]. WBC counts, NK activity, numbers of NK and T cells, and GRN, perforin, and GrA/B-expressing lymphocytes in the blood samples, the concentrations of estradiol and progesterone in serum, the concentrations of adrenaline and noradrenaline in urine were measured. The same control measurements were made before the trip on a normal working day. Blood was sampled at 8:00 am on all days. The concentrations of phytoncides in the forests were also measured.

The forest bathing trip significantly increased NK activity and the positive rates of NK (Figure 8), perforin-, GRN-, and GrA/B-expressing cells (Figure 9). The increased NK activity and the positive rates of NK, perforin, GRN, and GrA/B-expressing cells lasted for more than seven days after the trip [4], which confirmed the previous findings in male subjects [3]. Phytoncides, such as α-pinene and β-pinene were detected in forest air. These findings indicate that a forest bathing trip also increased NK activity, the number of NK cells, and the levels of intracellular anti-cancer proteins in female subjects, and that this effect lasted for at least seven days after the trip.

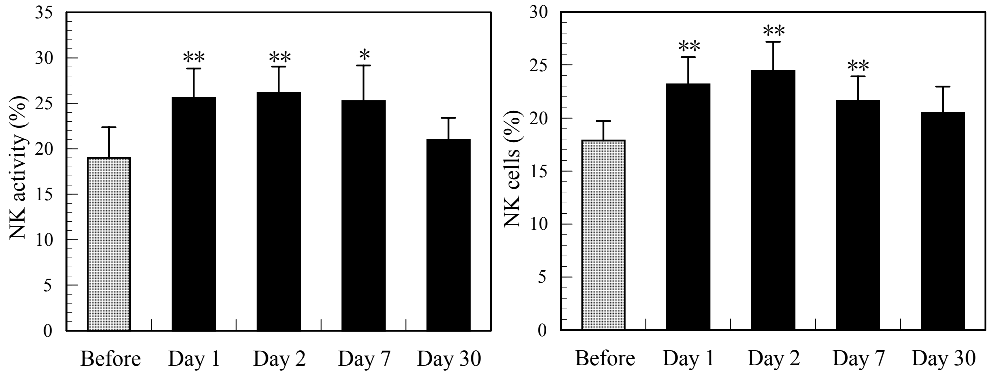

Figure 8. Effect of a forest bathing trip on NK activity and the percentage of NK cells in female subjects. Data are presented as the mean+SE (n=13). *: p<0.05, **: p<0.01, significantly different from before the trip by paired t-test. Cited from Li et al. J Biol Regul Homeost Agents. 2008;22:45-55 with permission from Biolife.

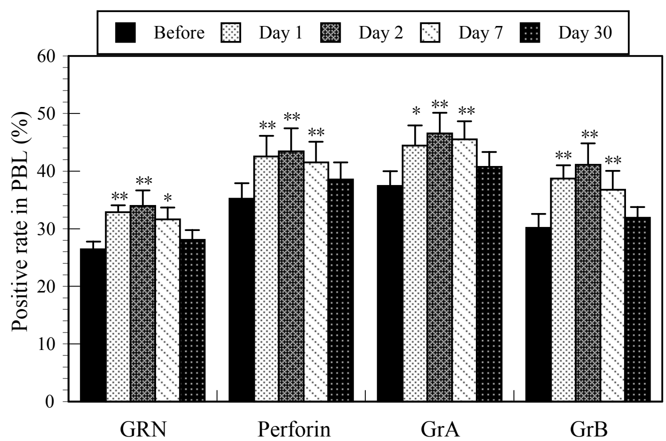

Figure 9. Effect of a forest bathing trip on the levels of GRN, perforin, and GrA/B-expressing cells in PBLs in female subjects. Data are presented as the mean+SE (n=13). *: p<0.05, **: p<0.01, significantly different from before the trip by paired t-test. Cited from Li et al. J Biol Regul Homeost Agents. 2008;22:45-55 with permission from Biolife.

It has been reported that the menstrual cycle and the levels of estradiol and progesterone in serum may affect human NK activity in female subjects [19-21]. To control for the influence of menstrual cycle on NK activity, a questionnaire was administered to obtain information on the menstrual cycle of the subjects. The ratios of subjects who were in the follicular phase during the experiment were 5/13, 6/13, 6/13, 7/13, and 6/13 on the day before the trip, days 1 and 2 during the trip, and days 7 and 30 after the trip, respectively, indicating that there was no significant difference in the proportion of the menstrual cycles of the subjects between the different days. This suggests that the menstrual cycle had a similar influence on the average of NK activity on the different days. In addition, there was no significant difference in the concentrations of estradiol and progesterone in the serum in the days before, during, and after the forest bathing trip, indicating that estradiol and progesterone had a similar effect on NK activity on different days in the subjects in this case [4].

Many factors, including circadian variation [22], physical exercise [13], and alcohol consumption [13, 23] can affect human NK activity. In order to control for the effect of circadian rhythm on NK activity, blood was sampled at 8:00 am on all days [2-6]. To control for the effect of physical exercise on NK activity, the walking steps during the trips were limited to the average normal workday distances as monitored by a pedometer. The levels of physical activity among all trips were also matched. To control for the effect of alcohol on NK activity, the subjects did not consume alcohol for two days before blood was drawn during the study period for both trips including before the trips and after the trips on days 7 and 30.

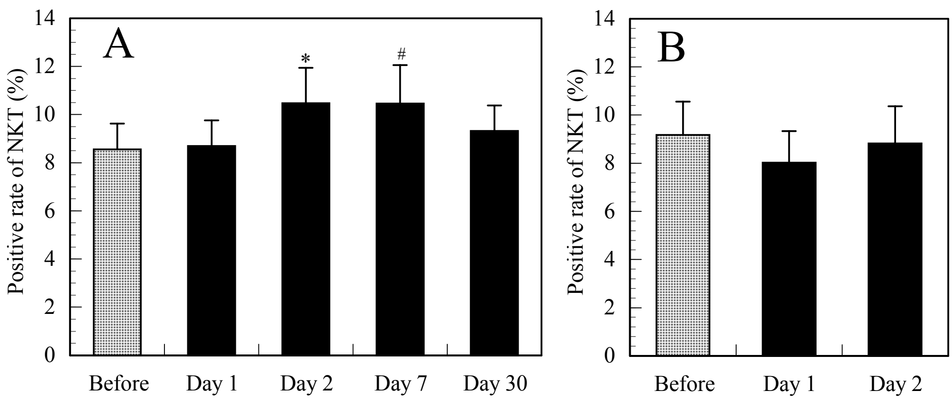

Figure 10. Effect of a forest bathing trip (A) *versus* a city tourist visit (B) on NKT cells in PBL. Data are presented as the mean+SE (n=12 in A and n=11 in B). Two-way ANOVA with no-repeated measures indicated that the forest bathing trip (p<0.05) and the variability between individuals (p<0.01) significantly affected the percentage of NKT cells. *: *p*<0.05, #: p=0.056 significantly different from before the trip by paired t-test.

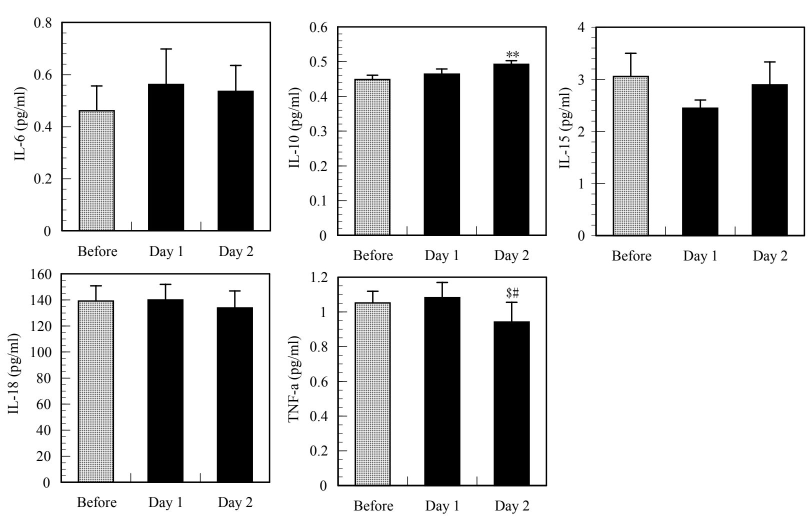

Figure 11. Effect of forest bathing on the levels of selected cytokines in plasma. Data are presented as the mean+SE (n=12). #: p=0.071, **: p<0.01, significantly different from before the trip, $: *p*<0.05 significantly different from day 1 by paired t-test.

Effect of Forest Environments on Human NKT Cells

Although it has been reported that forest bathing trips significantly affect human NK and activity, NK cell number, and the intracellular perforin, GrA, GrB, and GRN levels (2-4, 6), there have been no reports exploring the effect of forest bathing on human NKT cells so far. NKT cells were originally named because of the co-expression of a T-cell receptor (TCR) along with typical surface receptors for NK cells including CD16, CD56, CD161, CD94, CD158a, and CD158b [24, 25]. Two subtypes of CD1d-restricted NKT cells have been identified. Type I NKT cells, also called invariant NKT (iNKT) cells, have a highly restricted T-cell receptor (TCR) repertoire and express TCR Vα14–Jα18 and Vβ8.2, -7 or -2 chains in mice and homologous TCR Vα24–Jα18 and Vβ11 chains in humans. Type II NKT cells, which are also referred to as non-iNKT cells, express a more diverse TCR repertoire [26]. The $CD56^+/CD3^+$ NKT cells are also called NKT-like cells [27]. NKT cells have been implicated in immune responses against infectious agents, tumors and tissue grafts and in regulating a variety of autoimmune, adaptive immune response, and inflammatory diseases [24, 26]. In the present study, twelve healthy male subjects, aged 35-56 years (mean 45.1±6.7), were selected from four large companies in Tokyo, Japan as described previously [3]. The subjects experienced a three-day/two-night trip to three different forest fields at Agematsu town in Nagano prefecture located in northwest Japan in early September, 2006 [3]. In contrast, in the city tourist visit, eleven subjects experienced a three-day/two-night trip to Nagoya city in mid-May, 2006 [3]. Blood was sampled on the second and third days during the trips, and on days 7 and 30 after the forest bathing trip, and three days prior to the trips as a control. $CD56^+/CD3^+$ NKT cells were determined by flow cytometry. The forest bathing trip significantly increased the percentage of $CD56^+/CD3^+$ NKT cells, and this increase lasted more than 7 days after the trip (Figure 10A). In contrast, the city tourist visit did not increase human $CD56^+/CD3^+$ NKT cells (Figure 10B) [28]. Taken together, these findings indicate that forest bathing trips significantly increases the positive rate of human $CD56^+/CD3^+$ NKT cells in PBL.

Effect of Forest Bathing on Selected Cytokines

The levels of IL-6, IL-10, IL-12 and IL-18, and TNF-alpha in plasma were measured using ELISA kits according to the manufacturers' instructions. The forest bathing trip significantly increased the level of IL-10 and decreased the level of TNF-alpha in plasma, but did not affect the levels of IL-6, IL-15, or IL-18 in plasma (Figure 11).

Forest Environments Influence NK Activity through Stress Hormones

The concentrations of adrenaline and noradrenaline in urine have been used to evaluate work related stress in nurses [29] and lorry drivers [30], in which the subjects showed decreases in adrenaline and/or noradrenaline in urine with the lower stress. It was found that forest bathing trips significantly decreased adrenaline and/or noradrenaline concentrations in urine in both male [3] (Figure 12A) and female (Figure 12CD) [4] subjects, while a city tourist visit had no effect (Figure 12B) [3]. In addition, day trips to a forest park also significantly decreased adrenaline and/or noradrenaline concentrations in urine in males [6, 31]. These findings suggest that the subjects were under conditions of lower stress during the forest bathing trips [3-4].

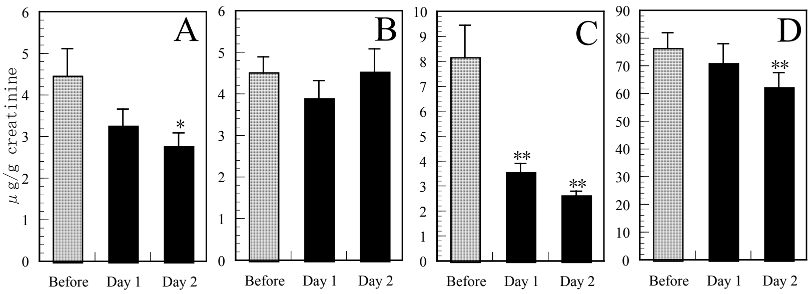

Figure 12. Effect of a forest bathing trip on adrenaline and noradrenaline concentrations in urine. A: Effect of a forest bathing trip on urinary adrenaline concentration in male subjects (n=12), B: Effect of a city trip on urinary adrenaline concentration in male subjects (n=11), C: Effect of a forest bathing trip on urinary adrenaline concentration in female subjects (n=13), D: Effect of a forest bathing trip on urinary noradrenaline concentration in female subjects (n=13). Data are presented as the mean+SE. *: p<0.05, **: p<0.01, significantly different from before the trip by paired t-test. Cited from Li et al. Int J Immunopathol Pharmacol. 2008;21:117-128 and Li et al. J Biol Regul Homeost Agents. 2008;22:45-55 with permission from Biolife.

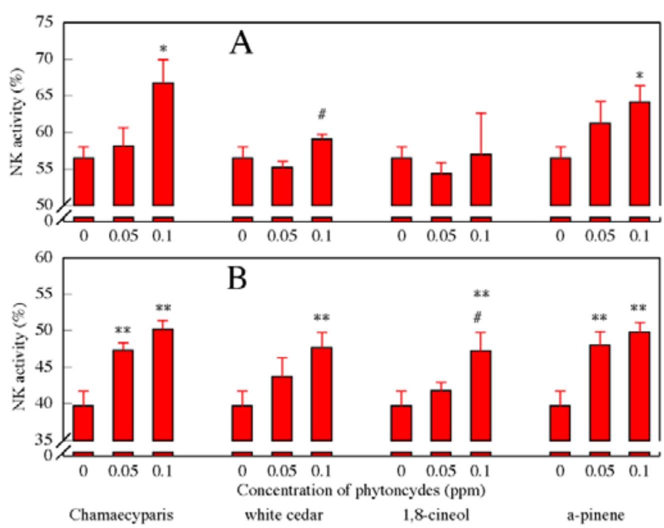

Figure 13. Effect of phytoncides on NK activity of NK-92MI cells exposed for 120h (A) and 144h (B). One-way ANOVAs indicated that 4 of the phytoncides significantly affected NK activity for 120h (A) and 144h (B) (all p<0.05) but 1,8-cineole at 120h did not. *: *p*<0.05, **: *p*<0.01, significantly different from 0 ppm, #: *p*<0.05 significantly different from 0.05 ppm by Tukey's method. Cited from Li et al. Immunopharmacol Immunotoxicol. 2006;28:319-33 with permission from Informa Healthcare.

It has been reported that adrenaline inhibits human NK activity [32]. Moreover, a day trip to a forest park also significantly decreased the concentrations of cortisol in plasma [6]. It has been demonstrated that cortisol inhibits NK activity both *in vitro* and *in vivo* [33-34]. Li et al. [10] found previously that physical and/or psychological stress decreased NK activity, NK receptor levels, and mRNA transcription levels of granzymes and perforin by increasing plasma corticosterone level in mice. The increase in NK activity during forest bathing trips may be related to an attenuated stress hormone response (adrenaline and cortisol) associated with the forest bathing trip, whereas increased sympathetic activity may have an immunosuppressive effect through the release of adrenaline. Other studies have reported that forest bathing trips reduce the concentration of cortisol in saliva, reduce prefrontal cerebral activity, reduce blood pressure and sympathetic nervous activity, and increase parasympathetic nervous activity in humans [8]. In addition, forest bathing trips significantly increased scores for vigor and decreased the scores for anxiety, depression, and anger in the POMS test, suggesting that the subjects were physiologically relaxed during the forest trips [2, 4, 5-6].

Mechanism of Forest Environment-Induced Increase in NK Activity

Why did the forest environment increase human NK activity? What factors in the forest environment activated human NK cells? We speculate that aromatic volatile substances (phytoncides) derived from trees such as α-pinene and limonene play an important role. We detected several phytoncides, such as isoprene, α-pinene, β-pinene, and *d*-limonene, in the forest parks during the trips. To investigate the effect of phytoncides on human NK function, NK-92MI cells, a human NK cell line, were incubated in the presence of phytoncides such as α-pinene, 1,8-cineole, *d*-limonene, and essential oils extracted from trees including Japanese cedar and *Chamaecyparis obtusa* (Hinoki in Japanese), then NK activity and the intracellular levels of perforin, GrA, and GRN were measured [1]. Phytoncides significantly increased the cytolytic activity of NK-92MI cells in a dose-dependent manner (Figure 13) and significantly increased the intracellular levels of perforin, GrA, and GRN in NK-92MI cells. Phytoncides also partially, but significantly, restored the decreased human NK activity and the decreased perforin, GrA, and GRN levels in NK-92MI cells induced by dichlovos [1]. da Silva et al. [35] found that volatile oil from Zanthoxylum rhoifolium Lam leaves and certain terpenes (α-humulene, ß-caryophyllene, α-pinene, and ß-pinene) exhibited anti-tumor efficacy and significant immunomodulatory action *in vivo* and *in vitro* in mice. Moreover, Grassmann et al. [36] found that the essential oil from *Pinus mugo* showed antioxidative properties. These findings mentioned above strongly suggest that phytoncides have beneficial effects on human immune function. Thus, we further investigated the effect of tree-derived phytoncide exposure on human immune function in male subjects in vivo. In the in vivo study, twelve healthy male subjects, age 37-60 years, were selected with informed consent. The subjects stayed at an urban hotel for 3 nights. Aromatic volatile substances (phytoncides) were produced by vaporizing *Chamaecyparis obtusa* stem oil with a humidifier in the hotel room during the night stay. Blood was sampled on the last day and urine was sampled every day during the stay. Similar control measurements were made before the stay on a normal working day.

The concentrations of phytoncides in hotel room air were measured. Phytoncide exposure significantly increased NK activity (Figure 14A) and the numbers of NK (Figure 14B), perforin, GRN, and GrA/B-expressing cells (Figure 15), and significantly decreased the concentrations of adrenaline and noradrenaline in urine. These findings indicate that phytoncide exposure and decreased stress hormone levels may partially contribute to increased NK activity [9]. Komori et al. [37] reported that citrus fragrance found in forest affects the human endocrine and immune systems as analyzed by the measurement of urinary cortisol and dopamine levels, NK activity, and CD4/8 ratios. Sun and Peng [38] also found that triterpenoid fractions from the rhizomes of Astilbe chinensis provide significant protection against cyclophosphamide-induced inhibition in murine NK activity. β-Carotene is an organic compound, a terpenoid, a red-orange pigment abundant in plants and fruits. Santos et al. [39] found that β-carotene induced enhancement of NK activity in elderly men lived in Boston-area in a randomized, placebo-controlled, double-blind study, suggesting that terpenes can activate NK cells.

These findings suggest that phytoncides including terpenes contributed to the enhanced NK activity during the stay at the hotel. These findings also suggest that phytoncides contribute to the enhanced NK activity during the forest trip. The Swedish occupational exposure value for a mixture of monoterpenes (phytoncides) and a single monoterpene is 150 mg/m^3 (27 ppm) and the Finnish occupational exposure limit is 570 mg/m^3 (102 ppm) [40, 41]. The concentrations of α-pinene (less than 1 ppm) and total phytoncides (less than 2 ppm) in the hotel room air in the present study were far less than the occupational exposure values, suggesting that phytoncide exposure will not have any adverse effects on human health, including immune function, and that phytoncide exposure at the present concentration should be safe for human health.

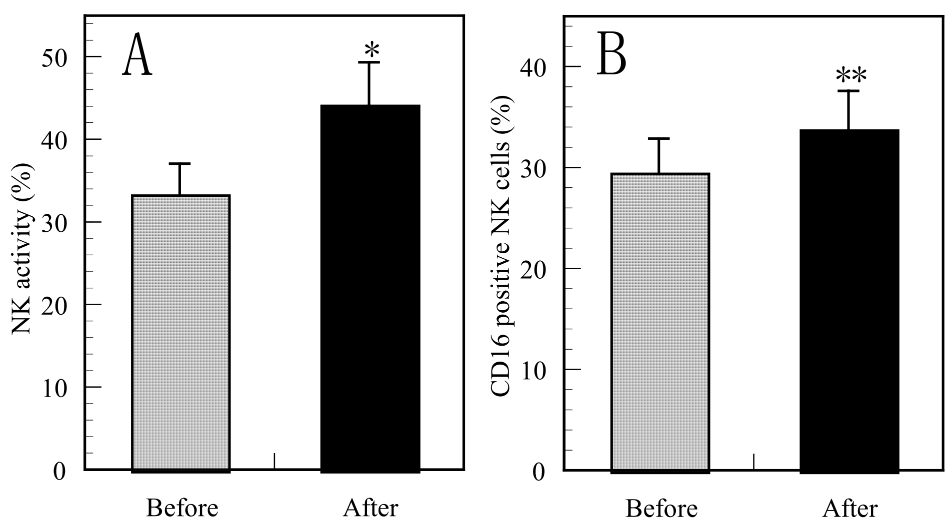

Figure 14. Effect of phytoncides on human NK activity (A) and the percentage of $CD16^+$ NK cells (B). Data are presented as the mean+SE (n=12). *: p<0.05, **: p<0.01 significantly different from before the exposure by paired t-test. Cited from Li et al. Int J Immunopathol Pharmacol. 2009;22:951-9 with permission from Biolife.

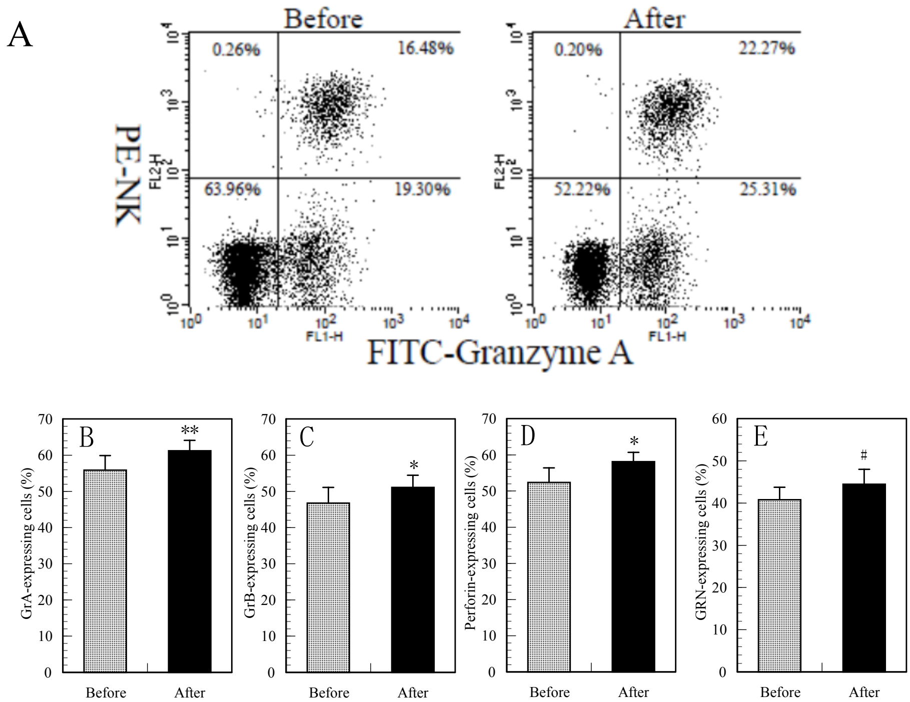

Figure 15. Effect of phytoncides on the percentage of GrA/B- (A-C), perforin (D)-, and GRN (E)-expressing cells in PBLs. A: Dot plots of FITC-GrA/PE-CD16-positive cells in PBLs of a subject before (left) and after (right) phytoncide exposure. The horizontal axis shows the intensity of fluorescence of FITC-GrA, while the vertical axis shows the intensity of fluorescence of PE-CD16 (NK cells). Percentages in quadrants 2 and 3 show $GrA^+/CD16^+$ and $GrA^+/CD16^-$ cells, respectively. Data are presented as the mean+SE (n=12). *: p<0.05, **: p<0.01 significantly different from before the exposure by paired t-test. Cited from Li et al. Int J Immunopathol Pharmacol. 2009;22:951-9 with permission from Biolife.

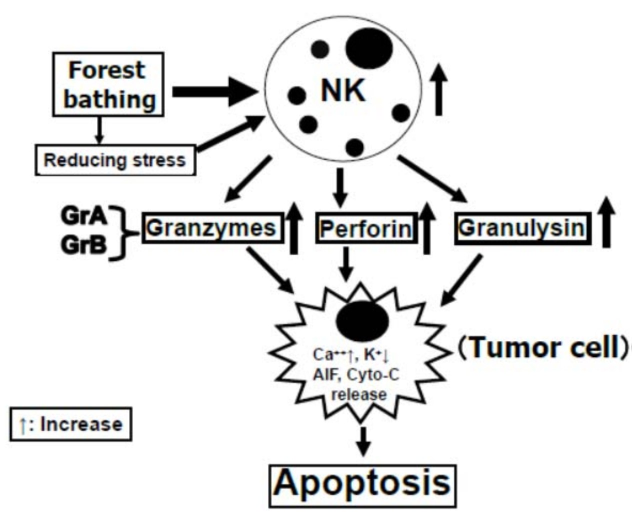

Figure 16. Mechanism of forest bathing-induced induction in NK activity. Cited from Li et al. Int J Immunopathol Pharmacol. 2011; 24 (S1): 39-44 with permission from Biolife.

In addition, we found that people living in areas with lower forest coverage had significant higher standardized mortality ratios for cancers compared with the people living in areas with higher forest coverage in Japan, suggesting that forest environments may partially contribute to decreased mortality ratios for some cancers [9].

Conclusions

These findings indicate that forest environments increase NK activity, which was mediated by increases in the number of NK cells and the levels of intracellular anti-cancer proteins [7]. Phytoncides released from trees as well as decreased production of stress hormones may also partially contribute to the increased NK activity (Figure 16) [42]. Because NK cells can kill tumor cells by releasing anti-cancer proteins, such as perforin, GRN, and GrA/B, and forest bathing trips increase NK activity and the intracellular level of anti-cancer proteins, the above findings suggest that forest bathing trips may have a preventive effect on cancer generation and development.

Acknowledgments

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Chapter 7

Effect of Forest Environments on the Human Endocrine System

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Abstract

Forest environments affect the human immune system and sympathetic and parasympathetic nervous systems. They also alter levels of some hormones. This chapter reviews the effect of forest environments on the endocrine system. Walking in the forest setting can significantly reduce urinary levels of adrenaline and noradrenaline, stress hormones, in both males and females, as well as the concentration of cortisol in saliva. However, the effects on serum cortisol levels are inconsistent. Forest environments also have beneficial effects on adiponectin, a hormone in serum produced specifically by adipose tissue, and dehydroepiandrosterone sulfate (DHEA-S), a secretory product of the adrenal gland, the levels of which decline dramatically with age. On the other hand, forest environments did not affect serum estradiol and progesterone levels in females, or serum insulin, free triiodothyronine and thyroid-stimulating hormone levels in males.

Keywords: Adiponectin, Adrenaline, Cortisol, DHEA-S, endocrine system, Forest environment, Noradrenaline

Introduction

Forest environments have long been enjoyed for their quiet atmosphere, beautiful scenery, mild climate, and clean air. A short, leisurely trip to a forest park, called “Shinrinyoku” (forest bathing) in Japanese, to breathe in phytoncides, volatile organic substances derived from trees, such as α-pinene and limonene, can have similar effects to

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natural aromatherapy [1-9]. Incorporating forest trips into a healthy lifestyle was first proposed in 1982 by the Forest Agency of Japan [5, 10], and has now become a well-recognized relaxation and/or stress management activity [1-8, 11-13]. Forests occupy 67% of Japan, and so are readily accessible [14]. Moreover, forest bathing is possible throughout much of the world. Forest bathing trips significantly increase natural killer (NK) activity and levels of intracellular anti-cancer proteins and have beneficial effects on the immune system [1-6]. Moreover, they reduce sympathetic nerve activity, increase parasympathetic nerve activity, and stabilize autonomic nervous activity [8, 12-13]. Several articles have also reported effects of forest environments on levels of some hormones, especially stress hormones [2-5, 12]. This paper will review the effect of forest bathing trips on the endocrine system.

Effect of Forest Environments on Human Urinary Adrenaline in Male Subjects

Adrenaline is released from the adrenal medulla, and adrenaline levels increase as a result of novelty, anticipation, unpredictability, and general emotional arousal. Noradrenaline is the predominant neurotransmitter released by the sympathetic system, and some of it enters the blood; the level of noradrenaline increases during increased physical activity [15]. Levels of free adrenaline and noradrenaline in urine provide a reliable measure of the concentrations of adrenaline and noradrenaline in the bloodstream and thus a measure of sympathoadrenal medulla activity [16].

The concentrations of adrenaline and noradrenaline in urine have been used to evaluate work-related stress in nurses [17] and lorry drivers [18], in which the subjects showed decreases in adrenaline and/or noradrenaline in urine with lower stress. Forest environments may reduce stress and have a relaxing effect. Thus, we speculate that walking in a forest park may reduce the urinary adrenaline levels. To investigate the effect of forest environments on urinary adrenaline levels, twelve healthy males, aged 35-56 years (mean 45.1±6.7), were selected from four large companies in Tokyo, Japan [2]. Information gathered from a self-administered questionnaire, including questions about cigarette smoking, alcohol consumption, eating breakfast, sleeping hours, working hours, physical exercise, nutritional balance, and mental stress, has been reported previously [2, 19]. Written informed consent was obtained from all subjects after a full explanation of the study procedures. The Ethics Committee of the Nippon Medical School approved the study. The subjects experienced a three-day/two-night trip to three forest fields at Agematsu town in Nagano prefecture located in northwest Japan in early September, 2006. On the first day, the subjects walked for two hours in the afternoon in a field, and then stayed at a nearby hotel within the forest. On the second day, the subjects walked for 2 hours each in the morning and afternoon, in two different forest fields. On day 3, the subjects finished the trip and returned to Tokyo after providing urine samples and completing the questionnaire.

In contrast, in the city trip, eleven subjects experienced a three-day/two-night visit to Nagoya city located in Aichi prefecture roughly in the center of Japan in mid-May, 2006. On the first day, the subjects walked for two hours in the afternoon along a tourist route, which passes through an old style district in Nagoya, and then stayed at a hotel in Nagoya. On the second day, the subjects walked for 2 hours around Nagoya Baseball Dome in the morning and 2 hours in/around Nagoya airport nearby Nagoya city in the afternoon. There are some areas of trees in Nagoya city, but there are almost no trees in the areas visited. The class of hotel was the same and the hotel experience was the same for the city and forest trips. The distance between Tokyo and the forest fields at Agematsu is almost the same as that between Tokyo and Nagoya. Each course in both trips was 2.5 km, closely resembling normal physical activity for the subjects on an average normal working day. Daily physical activity was monitored with a pedometer for a week, and the average walking distance for the subjects overall was about 5.0 km/day. We set the walking distances in both trips based on this result. The duration of sleep was measured with a piezo-electric accelerometer, Actiwatch(R) (Mini Mitter Co. Inc., Sunriver), worn on the wrist of the non-dominant arm. Validation was reported previously [20]. Urine was sampled on the second and third days of the trips, and three days prior to the trips as a control.

Adrenaline and noradrenaline concentrations in urine were determined by HPLC. It was found that the forest bathing trips significantly decreased adrenaline concentrations in urine in the male subjects (Figure 1A) [2], while the city visit had no effect (Figure 1B) [2], suggesting that the subjects were under less stress in the forest environment [1-2]. In addition, the forest environment significantly increased the score for vigor and decreased the scores for anxiety, depression, and anger in the POMS test, suggesting that the subjects were physiologically relaxed [1, 3, 4].

Moreover, the forest bathing trip significantly increased proportions of lymphocytes and monocytes and decreased proportions of granulocytes in WBCs [1]. It has been reported that dominance by the parasympathetic nervous system causes an increase in circulating lymphocytes and decrease in granulocytes in peripheral blood [21]. This suggests indirectly that the parasympathetic nervous system was dominant, which is associated with relaxation and decreased stress, during the forest bathing trips. In addition, phytoncides, such as α-pinene and β-pinene were detected in forest air [1-4].

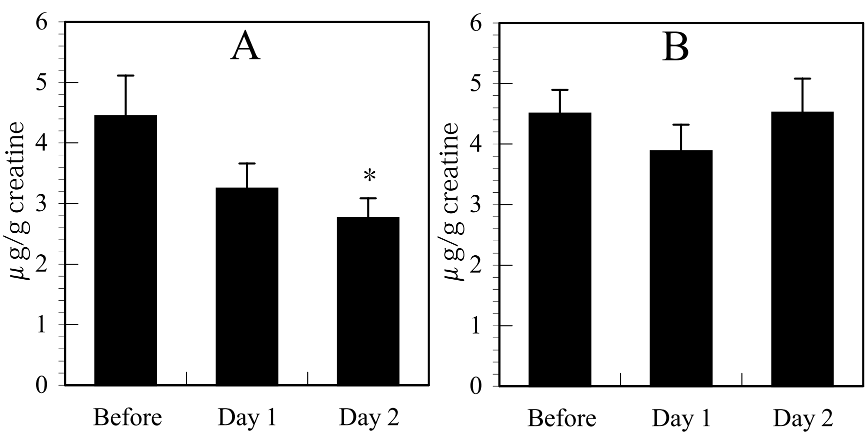

Figure 1. Effect of the forest bathing trip (A) and city visit (B) on urinary adrenaline concentrations in male subjects. Data are presented as the mean+SE (n=12 in A and n=11 in B). Two-way ANOVA with no-repeated measures indicated that the forest bathing trip significantly affected the adrenaline concentration in urine ($p<0.05$). *: $p<0.05$, significantly different from before the trip by paired t-test. Cited from Li et al. Int J Immunopathol Pharmacol. 2008;21:117-128 with permission from Biolife.

Effect of a Day Trip to a Forest Park on Urinary Adrenaline and Noradrenaline Levels in Male Subjects

Although a three-day/two-night trip to a forest park significantly reduced urinary adrenaline concentrations, it is not clear whether a day trip to a forest park would have the same effect. In this study [4], twelve healthy male subjects, aged 35-53 years (mean: 44.4±5.7), were selected from two large companies in Tokyo, Japan. Information gathered from a self-administered questionnaire, including age and lifestyle habits, has been reported previously [1-3]. Written informed consent was obtained from all subjects after a full explanation of the study procedures. The Ethics Committee of the Nippon Medical School approved the study. The subjects experienced a day trip to a forest park in Saitama Prefecture located in the north of Tokyo, Japan on a Sunday at the end of July 2009. The subjects walked for two hours each in the morning and afternoon for a total of about 6 km in the forest park, and then returned to Tokyo. The POMS test was conducted before, during, and after the walk. The physical activity of the subjects was monitored with a pedometer [1-3]. The adrenaline concentration in urine and cortisol concentration in serum were determined before and after the trip. As shown in Figure 2, the difference in the concentrations of adrenaline between before and after the trip was not significant (p=0.71, Figure 2B). However, when the subjects were divided into two groups: an increased group (2 subjects) and a decreased/unchanged group (10 subjects), it was found that there was a significant decrease in the decreased/unchanged group (10 subjects, p=0.04) (Figure 2B), indicating individual differences in the response to the trip (Figure 2A) [4]. These findings indicate that a day trip to a forest park also significantly decreased the concentrations of adrenaline in urine, confirming our previous findings [2-3], and suggesting that the subjects had lower stress levels during the forest trip.

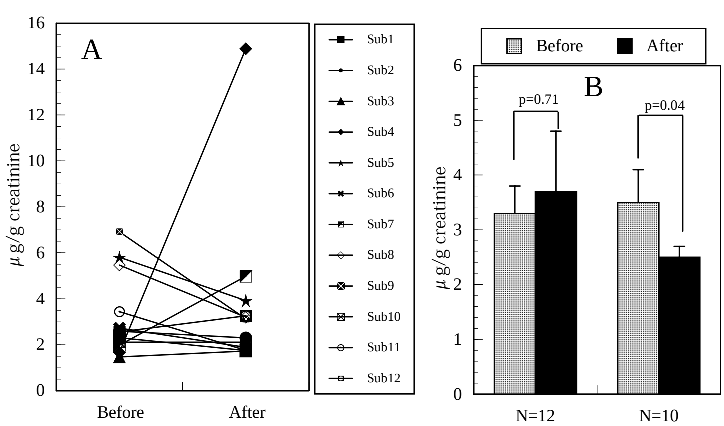

Figure 2. Effect of a day trip to a forest park on the urinary adrenaline concentration in male subjects. A: Urinary adrenaline levels in 12 subjects, B: data are presented as the mean+SE (n=12 for all subjects and n=10 for subjects with a decreased/unchanged urinary adrenaline concentrations). Significance was analyzed by the paired t-test. Cited from Li et al. J Biol Regul Homeost Agents. 2010;24:157-65 with permission from Biolife.

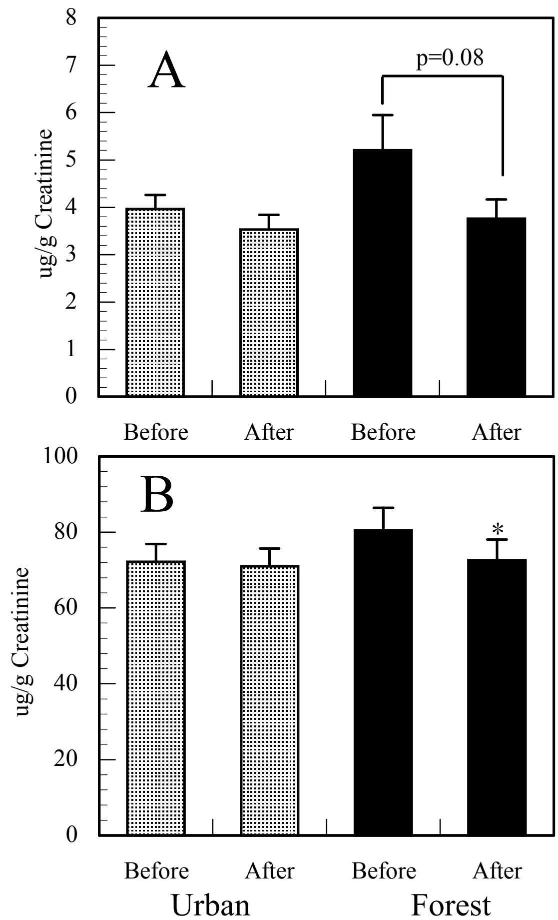

Figure 3. Effect of a day trip to a forest park/urban area on urinary adrenaline (A) and noradrenaline (B) concentrations in male subjects. Data are presented as the mean+SE (n=14). *: p<0.05, significantly different from before the forest bathing trip by paired t-test.

Moreover, another day trip to the forest park also significantly decreased urinary noradrenaline concentration. However, walking in urban areas did not affect the urinary adrenaline and noradrenaline concentrations (Figure 3) [7], suggesting that the subjects were physiologically relaxed during the forest bathing trips [1, 2, 4]. Phytoncides, such as α-pinene and β-pinene, were detected in the forest air [4].

Effect of Forest Environments on Urinary Adrenaline Levels in Female Subjects

Although it has been demonstrated that forest environments reduce urinary adrenaline levels in male subjects, it still remained to be resolved whether they also reduce adrenaline levels in female subjects.

In this study [3], thirteen healthy nurses, aged 25-43 years, with professional careers spanning 4-18 years, participated with informed consent. The Ethics Committee of the

Nippon Medical School approved the study. The subjects experienced a three-day/two-night trip to three forest fields at Shinano town in Nagano prefecture located in northwestern Japan in early September, 2007.

On the first day, the subjects walked for two hours in the afternoon in a field, and then stayed at a nearby hotel within the forest. On the second day, the subjects walked for 2 hours each in the morning and afternoon in two different forest fields, and then stayed at the same hotel. On day 3, the subjects finished the trip and returned to Tokyo after providing urine samples and completing a questionnaire. Each walking course was 2.5 km, closely resembling the normal physical activity for the subjects on an average working day. Daily physical activity was monitored with a pedometer [2-3] for a week, and the average walking distance of subjects overall was about 5.0 km/day. We set the walking distances in the trip based on this result.

Adrenaline and noradrenaline concentrations in urine were determined by HPLC before and after the trip. The schedule of the forest bathing trip and urine sampling was similar to that described previously [1-2]. The same control measurements were made before the trip on a normal working day. The concentrations of phytoncides in the forest were also measured. The forest bathing trip significantly reduced urinary adrenaline and noradrenaline levels in female subjects (Figure 4) [3], which confirmed the previous findings in males [2].

Moreover, as shown in Figure 1A and Figure 4, the females showed greater reductions in urinary adrenaline levels than the males (56.5% vs. 27.0% on day 1, 68.0% vs. 37.9% on day 2), suggesting that the females were more relaxed than the males during the forest bathing.

In addition, the forest bathing trips significantly increased the score for vigour and decreased the scores for anxiety, depression, anger, fatigue, and confusion in the POMS test [3], suggesting that the subjects were physiologically relaxed during the forest bathing trips [1-4]. Phytoncides, such as α-pinene and β-pinene, were detected in the forest air [3].

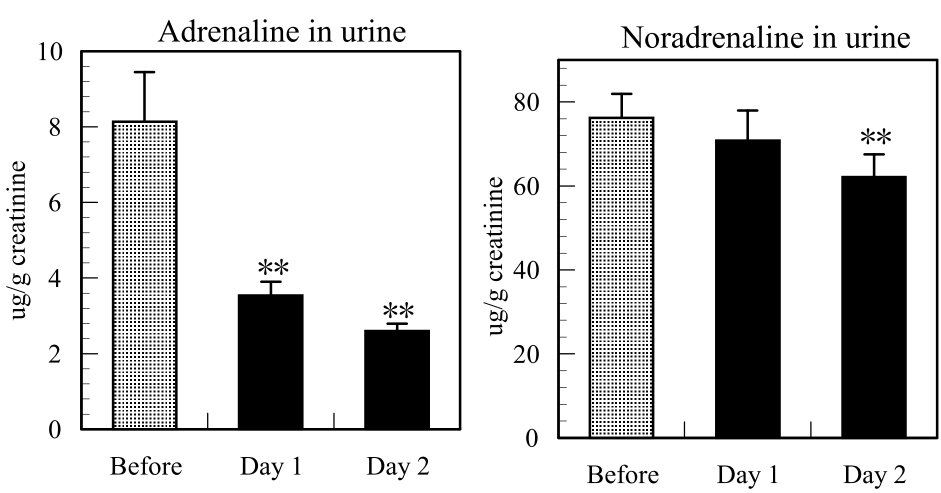

Figure 4. Effect of the forest bathing trip on urinary adrenaline and noradrenaline concentrations in female subjects. Data are presented as the mean+SE (n=13). Two-way ANOVA with no-repeated measures indicated that the forest bathing trip significantly affected the adrenaline concentration in urine ($p<0.01$). *: $p<0.05$, **: $p<0.01$, significantly different from before the trip by paired t-test. Cited from Li et al. J Biol Regul Homeost Agents. 2008;22:45-55 with permission from Biolife.

Mechanism Responsible for the Decrease in Urinary Adrenaline Levels

Why did the forest environment reduce urinary adrenaline levels? What factors in the environment were responsible for the reduction? We speculate that aromatic volatile substances (phytoncides) derived from trees such as α-pinene and limonene play an important role [10]. In fact, several phytoncides, such as isoprene, α-pinene, β-pinene, and *d*-limonene, were detected in the forests during the trips [1-4]. Thus, to investigate the effect of phytoncides on urinary adrenaline levels, twelve healthy males, aged 37-60 years (51.8± 7.3), were selected from a medical school in Tokyo, Japan [22]. The sociodemographic information on the subjects, including age and lifestyle habits, was obtained by means of a self-administered questionnaire and has been reported previously [1-7, 19]. Written informed consent was obtained from all subjects after a full explanation of the study procedures. The Ethics Committee of the Nippon Medical School approved this study. The subjects stayed in an urban hotel in Tokyo, Japan for three consecutive nights. On the first day, urine was sampled at 0700 at their homes, blood was sampled at 0830 at a hospital, and several questionnaires including the POMS test were completed as a control before the stay. The subjects then worked as usual. From 1900, all subjects stayed at the same hotel in the same type of room. During the 3 nights, aromatic volatile substances (phytoncides) were produced by vaporizing *Chamaecyparis obtusa* (hinoki in Japanese) stem oil with a humidifier in the hotel room for 3 consecutive nights. All subjects went to bed at 2300. During the experiment, the subjects got up at 0700, took a urine sample, completed the questionnaires and ate breakfast, and then went to their workplace and worked as usual. Daily physical activity was monitored with a pedometer [1-4]. Adrenaline and noradrenaline concentrations in urine were determined.

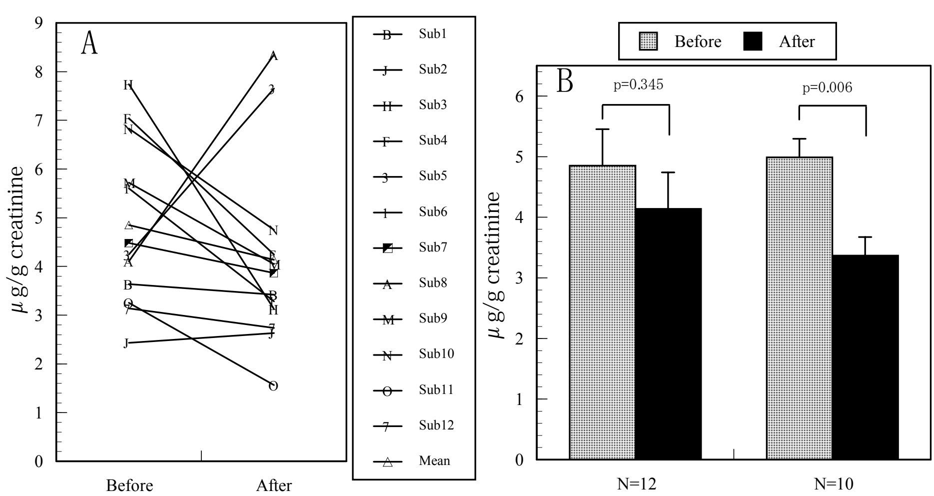

Figure 5. Effect of phytoncide exposure on urinary adrenaline concentrations. A: urinary adrenaline concentrations in 12 subjects, B: Data are presented as the mean+SE (n=12 for all subjects and n=10 for subjects with a decreased urinary adrenaline). Statistical significances were analyzed by paired t-test. Cited from Li et al. Int J Immunopathol Pharmacol. 2009;22:951-9 with permission from Biolife.

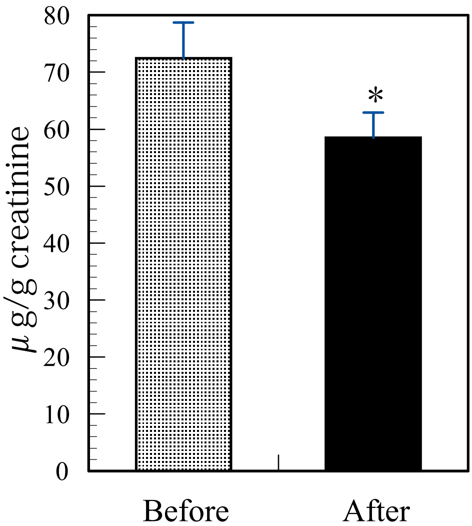

Figure 6. Effect of phytoncide exposure on urinary noradrenaline concentrations. Data are presented as the mean+SE (n=12). Statistical significance was analyzed by paired t-test. Cited from Li et al. Int J Immunopathol Pharmacol. 2009;22:951-9 with permission from Biolife.

Although phytoncide exposure decreased the concentrations of adrenaline, this decrease was not significant (p=0.345). However, when the subjects were divided into two groups: an increased group (2 subjects) and a decreased group (10 subjects), it was found that there was a significant decrease in the decreased group (p=0.006) (Figure 5B), indicating individual differences in the response to phytoncides. On the other hand, phytoncide exposure significantly decreased the concentrations of noradrenaline in urine (Figure 6). In addition, phytoncides significantly decreased the score for fatigue in the POMS test [22]. Komori et al. [23] also reported that a citrus fragrance affected the human endocrine system as analyzed by the measurement of urinary cortisol and dopamine levels, which supports our findings.

Effect of Forest Trips on Salivary and Serum Cortisol Levels

Park et al. [12] reported that forest viewing and walking significantly reduced the concentration of cortisol in saliva accompanied by a reduction in sympathetic nerve activity and an increase in parasympathetic nerve activity [8, 12-13]. We investigated the effect of forest bathing trips on serum cortisol concentrations in several experiments. As shown in Figure 7, the effects among the experiments were inconsistent. The three-day trip did not affect the level of cortisol in male or female subjects (Figure 7ABC) [1-3]. A day trip reduced the level in males (Figure 7D) [4]. In contrast, another day trip [7] increased the level in male subjects (Figure 7E). In addition, exposure to phytoncides through inhalation did not affect the level of cortisol (Figure 7F) [22]. However, the salivary samples were collected immediately after the visit to the forest [12]; whereas the serum samples were collected the next morning [1-4, 7]. It is necessary to collect the serum samples immediately after a forest visit.

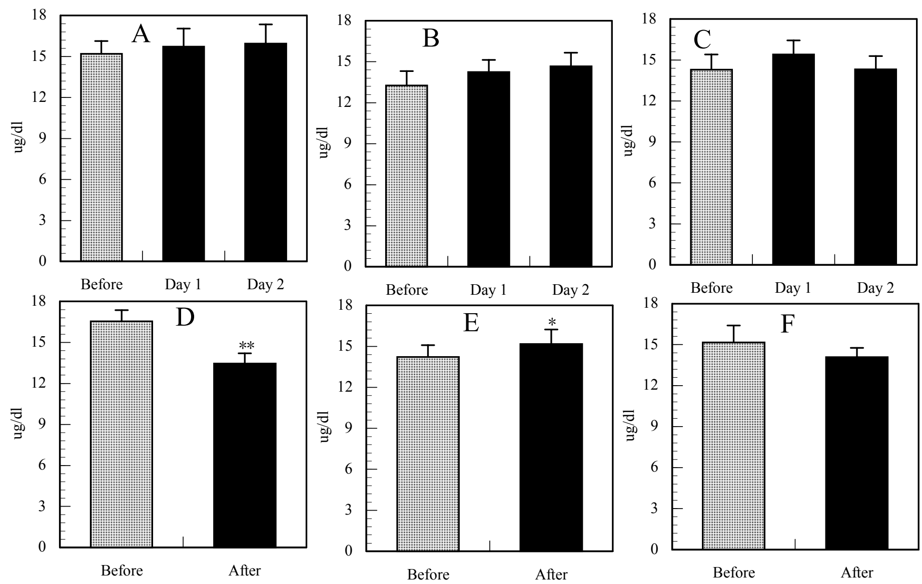

Figure 7. Effect of the forest bathing trips on the level of cortisol in serum.

Effect of a Forest Bathing Trip versus a City Visit on Serum DHEA-S Levels

The levels of DHEA and DHEA-S, the major secretory products of the adrenal gland, decline dramatically with age, concurrent with the onset of degenerative changes and chronic diseases associated with aging [24-25]. Epidemiological evidence suggests that DHEA-S has cardioprotective, antiobesity, and antidiabetic properties [24]. As shown in Figure 8, the forest bathing trip significantly increased the blood level of DHEA-S, but walking in an urban area had no effect, suggesting that the forest environment has beneficial effects on blood DHEA-S [7]. In males, acute exercise induces an increase in circulating DHEA-S levels. Such changes are directly related to the type of exercise, its intensity and duration, and to the subject's training status [26]. On the other hand, Tsai et al. [25] reported that resistance exercise induced a significant decrease at post-48h and post-72h. In the present study, there was no significant difference in physical activity between the walk in the forest park and that in the urban area suggesting that the difference in blood DHEA-S between the two trips was not due to physical activity. Antoni [27] reported that a cognitive behavioral stress management intervention induced a reduction in urinary noradrenaline levels (and reduced anxiety) and an increase in serum DHEA-S levels (and a reduced incidence of depressed moods). We also found that the increase in blood DHEA-S levels observed after the walk in the forest park was accompanied by a reduction in urinary noradrenaline levels in the present study [7]. Moreover, Brzoza et al. [28] reported that the DHEA-S concentration was negatively correlated with the level of anxiety and the level of depression in chronic urticaria patients and that the reductions in DHEA-S observed in chronic urticaria patients might be a phenomenon secondary to psychological disturbance. Taken together, the above findings suggest that stress affects the level of DHEA-S in serum.

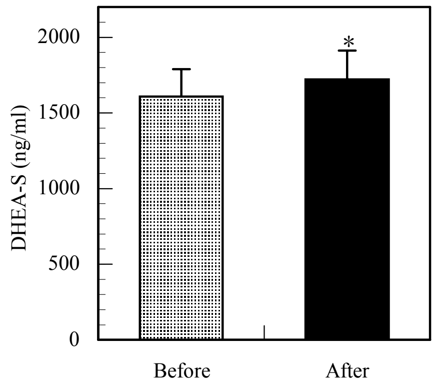

Figure 8. Effect of the forest bathing trips on the level of DHEA-S in male subjects. Data are presented as the mean+SE (n=16). *: p<0.05, significantly different from before the forest bathing trip by paired t-test.

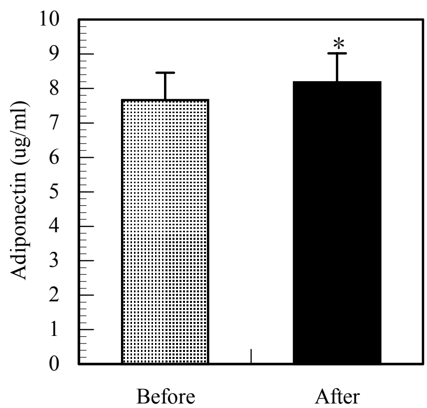

Figure 9. Effect of the forest bathing trips on serum adiponection levels in male subjects. Data are presented as the mean+SE (n=16). *: p<0.05, significantly different from before the forest bathing trip by paired t-test.

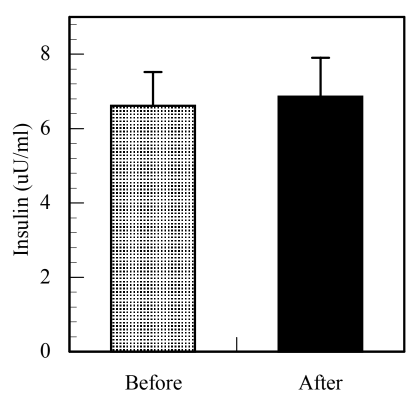

Figure 10. Effect of the forest bathing trips on serum insulin level in male subjects. Data are presented as the mean+SE (n=16).

Effect of a Forest Bathing Trip versus a City Visit on Serum Adiponectin Levels

Adiponectin (also called ARCP30 and AdipoQ) is a hormone specifically produced by adipose tissue. Studies have shown that lower than normal blood adiponectin concentrations are associated with several metabolic disorders, including obesity, type 2 diabetes mellitus, cardiovascular disease, and metabolic syndrome [29]. As shown in Figure 9, the forest bathing trip significantly increased the level of adiponectin in serum, but walking in an urban area had no effect, suggesting the forest environment to have a beneficial effect on serum adiponectin levels [7]. Although several studies have examined the effects of acute exercise on blood adiponectin levels, the results have varied [29-31]. In the present study, there was no significant difference in physical activity between walking in a forest park and walking in an urban area suggesting that the differences in blood adiponectin levels between the two trips were not due to physical activity. Taken together, the above findings suggest that the forest environment contributed to the increase in blood adiponectin levels seen in this study. However, further studies are necessary to explore why the forest environment increased the level of adiponectin.

Effect of a Forest Bathing Trip versus a City Visit on Serum Insulin Level

As shown in Figure 10, a day trip to a forest park did not affect serum insulin level in male subjects.

Effect of a Forest Trip versus a City Visit on Serum-Free Triiodothyronine (FT3) and Thyroid-Stimulating Hormone (TSH) Levels

As shown in Figure 11, a day trip to a forest park did not affect serum FT3 and TSH levels in male subjects.

Effect of Forest Bathing Trips on the Levels of Estradiol and Progesterone in Serum

There was no significant change in the concentration of estradiol in serum before, during, or after the trip. On the other hand, although the concentration of progesterone in serum on days 1 and 2 was higher than that before the trip, the difference was not significant (Figure 12) [3].

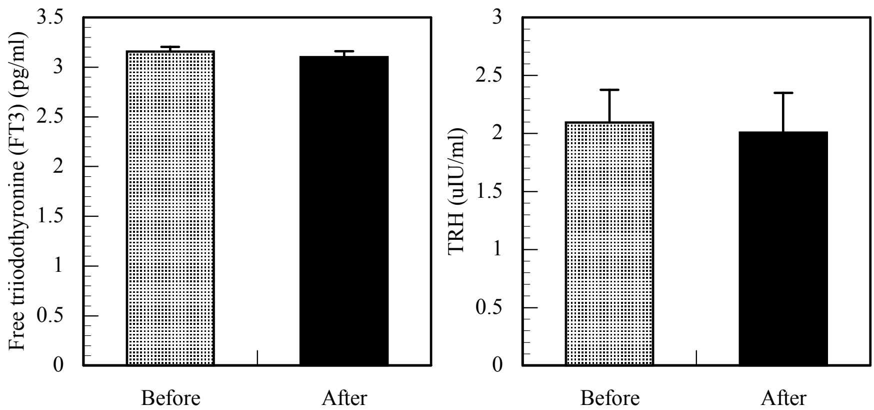

Figure 11. Effect of the forest bathing trip on serum FT3 and TSH levels in male subjects. Data are presented as the mean+SE (n=16).

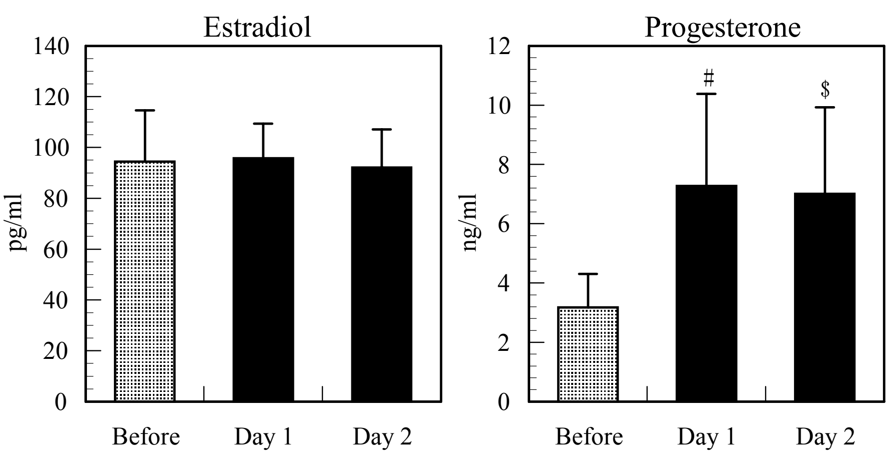

Figure 12. Effect of the forest bathing trip on serum estradiol and progestrone levels in female subjects. Data are presented as the mean+SE (n=13). #: p=0.084, $: p=0.090, between before and day 1 and between before and day 2, respectively by paired t-test.

Conclusions

Taking together, forest environments may reduce urinary adrenaline, and/or noradrenaline and salivary cortisol levels to produce a relaxing effect, and phytoncides from trees at least partially contribute to this effect. Forest environments may have beneficial effects on serum DHEA-S and adiponectin levels, but do not affect serum insulin, FT3 and TSH concentrations in male subjects and serum estradiol and progesterone levels in female subjects.

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Chapter 8

Effect of Forest Bathing on Sleep and Physical Activity

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Abstract

Objective: In order to explore the effect of a forest trip on human sleep, we performed continuous monitoring with an accelerometer, including during forest visits.

Methods: Twelve healthy male office workers in Tokyo, aged 37 to 55 years old, were selected for the study after obtaining their informed consent. The subjects undertook a three-day/two-night trip to three different forest fields. On the first day, they walked for two hours in the afternoon in a forest field; on the second day, they walked for two hours in the morning and in the afternoon, respectively, in two different forest fields. An accelerometer was used to monitor the duration of sleep and the daily physical activity level.

Results: Significant increase of the sleep time during the forest bathing trip was recognized as compared with that noted before the trip. In addition, there was also a significant increase of the daily physical activity during the trip as compared with that after the trip.

Conclusions: The authors speculate that the forest bathing trip might have had a beneficial effect on the sleep time, irrespective of the daily physical activity level.

Keywords: forest bathing, accelerometer, sleep time, daily activity

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Introduction

Forest bathing, called "Shinrinyoku" in Japanese, refers to the concept of visiting a forest field to improve physical health and emotional relaxation (Park et al., 2010; Morita et al., 2007). The cause-effect relationship between the desirable factors associated with forest bathing, such as "phytoncydes" and immunological competence has not yet been fully established, even though we have conducted intensive surveys on the effect of forest bathing on health, especially on the immunological competence (Li 2010; Li et al., 2010; Li et al., 2007). These findings strongly suggest that forest bathing is effective for health maintenance.

Among several lifestyle factors, adequate sleep time is also an important factor to maintain immunological competence. To examine the effect of forest bathing on human sleep, we investigated the duration of sleep and daily physical activity levels during the trip period in healthy subjects.

Methods

Twelve healthy male office workers, aged 37-55 years (43.1 ± 6.1), were selected. A self-administered questionnaire containing items on lifestyle habits, such as sleeping hours and daily physical activity, was administered, and the authors also planned to monitor both data using an accelerometer. In this study, the daily physical activity was defined as the summation of counts on the accelerometer from 9 AM to 5 PM.

Written informed consent was obtained from all subjects after providing them with=an explanation of the study protocol. None of the subjects showed signs or symptoms of illness during the surveys, and none was on any medication. The study was approved by the Ethics Committee of Nippon Medical School (approval No. 16-1).

Accelerometer

The sleep time and daily physical activity of the subjects was monitored with a piezoelectric accelerometer, Actiwatch® (Mini Mitter Co. Inc., Sunriver, OR), worn on the wrist of the non-dominant arm; the device was removed only if there was a likelihood of its getting wet. The sampling frequency of the Actiwatch was set at 32 Hz and the sensitivity at 0.05 g, using 1 min as the unit; the number of body movements was calculated by summing the active electricity counts. If the count was 40 or more, we judged the patient as awake. The count of 40 was adopted as the cutoff point between the sleeping and awake states (Benson et al., 2004). If the number of two epochs before the target epoch × 0.04 + number of one epoch before the target epoch × 0.2 + number of target epochs + number of one epoch after the target epoch × 0.2 + number of two epochs after the target epoch × 0.04 exceeded the threshold value, the subject was judged as awake. Using this algorithm, the agreement between the evaluation results using the Actiwatch and the sleep polygraph averaged over 24 nights, has been reported to be 88.4% and the Pearson’s correlation coefficient of the total sleep time calculated between the Actiwatch and the sleep polygraph was 0.848 (Kawada et al., 2001).

Forest Bathing Trip

The subjects undertook a three-day/two-night trip to three different forest fields in early September 2005. On the first day, the subjects walked for two hours in the afternoon in a forest field, and then stayed at a nearby hotel within the forest. On the second day, they walked for 2 hours in the morning and afternoon, respectively, in two different forest fields. They walked 2.5 km in 2 hours, closely resembling the normal physical activity of subjects on normal working days.

Statistical Analysis

Friedman's test with Wilcoxon's matched-pair signed-rank test was used for the analysis. The analysis was performed with the SPSS16.0J software for Windows. The significance level was set at $p< 0.05$. The significance level in the paired test was set at $p<0.016$, calculated by dividing 0.05 by a factor of 3.

Results

As there was a deficit of the data on the sleep time and daily activity before or after the trip for one subject, the remaining 11 sets of data were analyzed.

The mean sleep time before, during and after the trip was 383 minutes, 452, and 410 minutes, respectively. Significant increase of the sleep time during forest bathing trip was recognized as compared with that before the trip (Table 1). In addition, there was a significant increase of the daily physical activity during the trip as compared with that after the trip.

Discussion

The sleep time during forest bathing trip was 452 minutes, on average, significantly longer than that recorded before the trip (383 minutes). However, there was no significant difference in the mean daily physical activity level between during and before the trip. In contrast, the sleep time after the forest bathing trip was 410 minutes, on average, which was not significantly different from that during the trip, whereas, a significant difference was noted in the mean daily physical activity level between during and after the trip.

We previously reported that there was no significant difference in the number of NK cells or perforin, GRN or GrA/B-expressing cells in the PBL among in subjects who slept 5, 6 or 7 hours (Li et al., 2007), which was consistent with past reports (Kusaka et al., 1992; Inoue et al., 1996). In sleep deprivation studies, sleep deprivation has been reported to be associated both with an increase of the human NK activity (Matsumoto et al., 2001) and decrease of the human NK activity (Moldofsky et al., 1989). Although the sleep time during the forest bathing trip was significantly different as compared with that recorded sleep before the trip, there are controversies in the effect of sleep on NK activity.

Table 1. Sleep time and daily physical activity including the forest bathing trip

Variables	Before trip	During trip	After trip
Sleep time	383.4±77.8	452.1±75.6 *	409.8±49.4
Daily physical activity	109,658±42,089	155,424±41,414 #	129,735±37,621

Daily physical activity was defined as the summation of the counts on the accelerometer from 9 AM to 5 PM. Friedman's test showed that there was a significant difference among the three groups in the sleep time and daily physical activity level.

* Sleep time significantly increased during the trip as compared with that before the trip.

#: The daily physical activity increased significantly during the trip as compared with that after the trip.

There has been a lack of information on the direct association between forest bathing and sleep time in previous studies. There was a poor association between sleep time and the daily physical activity in our study, and we conclude that forest bathing can increase the sleep time, irrespective of the daily physical activity level.

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Chapter 9

Effect of the Forest Environment on Blood Glucose

Walking in a Forest is Beneficial for type 2 Diabetic Patients

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Abstract

The influence of "shinrin-yoku" (forest-air bathing and walking) on blood glucose levels in diabetic patients was examined. Forty-eight type 2 diabetic patients participated in the present study. Shinrin-yoku was performed nine times over a period of 6 years. The patients were divided into two parties. They then walked in the forest for 3 km or 6 km according to their physical ability and/or the existence of diabetic complications. The mean blood glucose level after forest walking changed from 186±6 to 109±4 mg/dl (mean±SEM, $p<0.005$). Blood glucose values declined by 79±10 mg/dl and 76±7 mg/dl after short- and long-distance walking respectively. There was no significant difference between these values. Since the forest environment causes changes in hormonal secretion and autonomic nervous functions, it is presumed that, in addition to the increased calorie consumption and improved insulin sensitivity, walking in a forest environment has other beneficial effects in decreasing blood glucose levels.

Keywords: Forest environment, Shinrin-yoku, Diabetic patient, Exercise

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Introduction

Daily exercise is fundamental to maintain well-controlled blood glucose levels in diabetic patients [1]. However, it is hard to continue exercise every day; therefore, walking around 10,000 steps a day is recommended for diabetic patients because walking exercise can be continued with a relatively little effort and effectively reduces the blood glucose levels in the patients [2].

On the other hand, diabetic patients who suffer from diabetic complications such as retinopathy, neuropathy and nephropathy should perform exercise therapy very carefully. Moreover, since cardiopulmonary dysfunction is often observed in the aged diabetic people, exercise therapy should be applied cautiously.

In Japan, walking in a forest environment and breathing the forest-air is called “shinrin-yoku”, which is very pleasant and refreshing. Volatile components emitted from the forest were reported to cause changes in physiological functions and have various biological activities. For example, blood pressure decreases, saliva secretion increases, salivary cortisol concentration tends to decrease and autonomic nervous activity becomes well balanced after shinrin-yoku [3, 4]. Therefore, shinrin-yoku is expected to have some good effects on the blood glucose levels.

In the present study, we performed shinrin-yoku for type 2 diabetic patients and investigated the changes of blood glucose levels to know if shinrin-yoku was useful for those patients.

Subjects and Methods

Forty-eight (16 male and 32 female) type 2 diabetic patients whose mean age was 66.8 years (range, 60-83), height and body mass index were 154.0±1.3 (mean±SEM) cm and 23.6±0.4 kg/m^2, participated in the present study. Among them, eleven patients experienced only dietary and exercise therapy, twenty-seven were medicated orally and ten by insulin administration. About 60 to 90 min after taking breakfast at home individually, they came to the hospital at 0830h in the morning. Peripheral venous blood samples were collected for glucose determination and then departed for the destination that was about 45 min away by bus. Prior to start of walking in a forest, preparatory exercise such as stretching themselves was performed for about 10 min. The patients were divided into two parties, then walked in the forest about 3-4 (short distance) or 6-7 (long distance) km according to their physical ability and/or the presence of diabetic complications. In both cases, about 10 min rest was given in the middle of the walking course. The second blood samples were taken after completion of the walking before lunchtime. No one complained of hypoglycemic symptoms nor feeling of sickness during and after walking. Shinrin-yoku had been performed for 9 times over 6 years and overall number of the participants came up to 116. The number of participation of each subject ranged from 1 to 8 (mean, 2.4). Twenty-five paired samples from normal subjects were obtained as a control. The Ethics Committee of the Hokkaido University School of Medicine approved this experiment and informed consent was obtained from all subjects. Student's t-test was used for statistical analysis. A probability level of 0.05 or smaller was used to indicate statistical significance. Results are expressed as means±SEM.

Result

It took about 5,000 and 10,000 steps, 30 and 60 min, in a short and a long distance walking, respectively. After every walking, blood glucose levels significantly decreased, and the mean values of 9 occasions declined from 186±6 to 109±4 mg/dl ($p<0.005$) in the patients and from 89 ± 3 to 82 ± 2 mg/dl ($p<0.05$) in normal controls (Table 1).

Blood glucose levels changed from 193±9 to 114±7 ($p<0.0005$) and from 181±8 to 106±5 mg/dl ($p<0.0005$) after short and long distance walking, respectively, and there was no significant difference in decrements between them (Table 2). Mean HbA1c values before walking was 7.5±0.3 % in patients from short distant walking and 6.5±0.4 % from long distance walking, and no significant difference was observed between them.

Discussion

Modern balneotherapy is consisted of exercise in the pool, walking indoors and outdoors and nutritional support with a conventional therapy. It is reported that blood glucose levels was improved by balneotherapy [5], in which walking for at least 10,000 steps a day is strongly recommended to the patients without severe diabetic complications. We performed shinrin-yoku twice a year as a part of educational programs for diabetic patients. In the forests, they were instructed to keep their own walking paces in order not to be tired out. Blood pressure in 31 patients tended to decrease from 147±6 / 82±3 to 138±6 / 81±3 (systolic / diastolic blood pressure, mmHg) after walking. Pulse rates in almost all subjects were around 90 beats/min at most, which were correspondent to 40 % maximum oxygen uptake (VO2max). Therefore, shinrin-yoku is not supposed to give a great load on cardiopulmonary system.

Decreased levels of blood glucose after shinrin-yoku suggest that walking in a forest is beneficial for diabetic patients. Since the subjects walked at a pace of 80-90 m/min for about 30-60 min, they were expected to consume 150-200 kcal by a short distance walking and 300-350 kcal by a long distance walking, respectively. It is very interesting that there was no significant difference in the amount of blood glucose decrement between short and long distance walking. Considering that no significant difference in HbA1c levels between short and long distance walking was observed, 3-4 km shinrin-yoku is thought to be enough for diabetic patients as an exercise therapy. Similar results were reported by Ohtsuka et al. previously [6].

Table 1. Blood glucose levels (mg/dl, mean±SEM) before and after walking

	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	mean	Control
Before	173± 15	187± 20	202± 17	205± 21	176± 13	175± 11	183± 20	222± 24	168± 18	186± 6	89± 3
After	113± 10*	107± 8*	110± 9*	112± 13*	118± 12*	120± 11*	98± 10*	124± 22*	86± 8*	109± 4*	82± 2**
n	15	15	13	11	15	12	11	10	14	116	25

* $p<0.005$, ** $p<0.05$, Before vs. After

Table 2. Blood glucose levels (mg/dl, mean±SEM) before and after walking at different walking distance

	Short distance (3-4 km)	Long distance (6-7 km)	Short vs. Long
Before	193±9	181±8	n.s.
After	114±7*	106±5*	n.s.
Δ Glucose	79±10	76±7	n.s.
n	50	66	

* $p<0.0005$ Before vs. After

The level of blood glucose was reported to decline by 13 mg/dl in diabetic patients after 30 min exercise with a cycle ergometer at the intensity of 75 % VO_{2max} [7]. Paternostro-Bayles et al. [8] reported that after 40 min exercise with a cycle ergometer at 40-50 % VO_{2max}, 16.5 mg/dl fall in blood glucose level was observed. About 40 mg/dl decrease was obtained by 3 h exercise with a cycle ergometer at 40 % VO_{2max} [9]. After a half-mile walk at 4 m.p.h. on a 2.5° treadmill slope, the glucose level decreased by 24.5 mg/dl [2]. Furthermore, the effect of thirty-minute underwater exercise in a pool filled with hot spring water (38 °C) on the blood glucose levels was investigated in the patients [10]. In this case, they were presumed to consume 200-250 kcal and the blood glucose value decreased by 21.2 % (48.6 mg/dl), while no changes were observed in the same patients when they did not perform underwater exercise. In the present study, after shinrin-yoku, the blood glucose levels decreased by 39.7 % (71 mg/dl), and this decrement was far greater than the values mentioned above (Table 3). These facts indicate that not only walking itself but forest environment has some beneficial effects on falls in the blood glucose levels in diabetic patients. In forest environment, there are volatile and non-volatile compounds called phytoncide, which are emitted by plants and have much influence on the other lives. For instance, it was reported that inhalation of Taiwan Hinoki wood oil was able to decrease blood pressure and stabilize autonomic nervous activity, and that after shinrin-yoku, salivary cortisol concentration tended to decrease [3]. Though Taiwan Hinoki did not exist in the areas we walked, same kinds of odoriferous substances were presumably present there. In addition to energy consumption by walking itself, so-called phytoncide is thought to be related to the decreased blood glucose levels.

Table 3. Effect of various exercises on blood glucose changes

	Long Distance Walking (6-7km)	Short Distance Walking (3-4km)	Bicycle Ergometer [6]	Bicycle Ergometer [7]	Bicycle Ergometer [8]	2.5°slope Treadmill 1.5 mile [2]	Under-water exercise (38°C) [9]
VO2max (%)	*40-50*	*40-50*	75	40-50	40	4mile/h	
Duration (min)	*60-70*	*30-40*	30	40	180	22.5	30
Energy (kcal)	*300-350*	*150-200*					200-250
Δ Glucose (mg/dl)	*70*	*74*	13	16.5	40	24.5	48.6

VO2max:maximum oxygen uptake, Energy:energy consumption

Numerous negative air ions are found in mountains, forests and hot spring areas and these ions give us feeling of refreshment [11]. By exposure to negative air ions, parasympathetic nervous activity is enhanced and blood glucose levels decreased [12]. It is assumed that large amount of negative air ions in a forest environment is another causative factor for decrement of blood glucose levels.

Conclusion

Shinrin-yoku successfully decreased blood glucose levels in type 2 diabetic patients. Both walking (exercise) and the forest environment contributed to the decrease in blood glucose observed in this study. However, further studies are necessary to explore why the forest environment decreased the levels of blood glucose. Since shinrin-yoku is a moderate exercise, it could be a useful exercise therapy for diabetic patients.

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Chapter 10

Effects of Forest Environments on Cardiovascular and Metabolic Parameters

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Abstract

To investigate the effects of forest environments on cardiovascular and metabolic parameters, sixteen healthy male subjects (mean age: 57.4±11.6 years) were selected after obtaining informed consent. The subjects took day trips to a forest park in the suburbs of Tokyo and to an urban area of Tokyo as a control in September 2010. On both trips, they walked for two hours in the morning and afternoon on a Sunday. Blood and urine were sampled on the morning before each trip and after each trip. Blood pressure was measured on the morning (0800) before each trip, at noon (1300), in the afternoon (1600) during each trip, and on the morning (0800) after each trip. The day trip to the forest park significantly reduced blood pressure and urinary noradrenaline and dopamine levels and significantly increased serum adiponectin and dehydroepiandrosterone sulfate (DHEA-S) levels. Walking exercise also reduced the levels of serum N-terminal pro-B-type natriuretic peptide (NT-proBNP), blood HbA1c and urinary dopamine. However, forest environments did not affect the levels of triglycerides, total Cho, LDL-Cho, HDL-Cho, RLP-Cho, insulin, or hs-CRP in serum, blood glucose, or hematological parameters. Taken together, habitual walking in forest

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environments may lower blood pressure by reducing sympathetic nerve activity and have beneficial effects on blood adiponectin and DHEA-S levels, and habitual walking exercise may have beneficial effects on blood NT-proBNP levels.

Keywords: Adiponectin, Adrenaline, Blood pressure, DHEA-S, Forest environment, NT-proBNP, Walking

Introduction

Humans enjoy forest environments because of the quiet atmosphere; beautiful scenery; mild climate; and fresh, clean air. It has been reported that walking in forest environments significantly enhances human immune function; reduces the levels of stress hormones, such as urinary adrenaline and noradrenaline; and increases the score for vigor and decreased the scores for anxiety, depression, fatigue, confusion and anger on the Profile of Mood States (POMS) test [1-4]. Moreover, forest environments reduce sympathetic nervous activity, increase parasympathetic nervous activity, and have a relaxing effect on humans [1, 5]. Since forests occupy 67% of the land in Japan [6], forest parks are easily accessible; therefore, walking in forest parks is very popular in Japan. Based on the findings mentioned above, because forest environments reduce sympathetic nervous activity and increase parasympathetic nervous activity, we speculated that walking in forest environments reduces blood pressure and has beneficial effects on cardiovascular function. Thus, in the present study, we investigated the acute effects of walking in a forest park on blood pressure and other cardiovascular and metabolic parameters in male subjects [7].

Subjects and Methods

Subjects

Sixteen healthy male subjects, who ranged in age from 36-77 years (mean±SD: 57.4±11.6), were selected for the present study. Information about the subjects gathered from a self-administered questionnaire that asked about cigarette smoking, alcohol consumption, eating breakfast, sleeping hours, working hours, physical exercise, nutritional balance, and mental stress have been reported previously [8]. Written informed consent was obtained from all subjects after a full explanation of the study procedures. None of the subjects had any symptoms of disease, used drugs that might have affected the results, or were taking any medication at the time of the study. The Ethics Committee of the Nippon Medical School approved this study.

Walking in a Forest Environment and an Urban Area

The subjects went on a day trip to a forest park in Saitama prefecture in the north of Tokyo, Japan, on September 12, 2010 (Sunday). As a control, on September 5, 2010

(Sunday), a week before they went walking in the forest park, the subjects took a day trip to an urban area in Tokyo where there were almost no trees. We previously found that the effects of walking in forest environments on the immune function (natural killer activity) lasted for more than one week, and sometimes even 4 weeks, but not walking in urban environments [2-4].

Therefore, to avoid such lasting effects, we designed the study so that all subjects first walked in the urban area and then in the forest. The interval between the two experiments was one week. The subjects walked for two hours each in the morning and afternoon for a total distance of about 6 km in the forest park/urban area and then returned to Tokyo. The subjects consumed the same number of calories during the two trips.

To control for the effects of alcohol, the subjects did not consume alcohol during the study period. Blood and urine were sampled on the morning before the trips and on the morning after the trips under fasted conditions. Blood pressure was measured before, during, and after the trips.

A questionnaire of the Profile of Mood States (POMS) test was conducted before, during, and after the trips as described previously [1-4]. The physical activity of the subjects was monitored with a pedometer [1-4]. The physical activity of the subjects was monitored with a pedometer, and their sleep duration was measured with an Actiwatch (R) piezo-electric accelerometer, (Mini Mitter Co., Inc., Sunriver) [1-4].

Blood Pressure Measurements

Blood pressure was measured on the right arm with an HBP-9020 automatic device (OMRON COLIN Co., Ltd., Tokyo) on the morning (0800) before the trips, at noon (1300), in the afternoon (1600) during the trips, and on the morning (0800) after the trips. The measurements were conducted after 10 min rest in a quiet room, and three measurements were taken at 30-second intervals. The mean of the last two measurements at each point was used for the statistical analysis.

Blood Analysis

The serum levels of triglycerides, total cholesterol (Cho), low density lipoprotein (LDL) Cho, high density lipoprotein (HDL) Cho, and remnant-like particles (RLP) Cho were analyzed using an enzymatic assay with an autoanalyzer. The serum total adiponectin concentration was measured using an enzyme immunoassay (EIA). Blood glucose concentration was analyzed using a Glucocard GT-1640 and Diasenser strips (Arkray, Kyoto, Japan). Glycated hemoglobin (HbA1c) concentration was measured by latex agglutination assay. The serum level of insulin was analyzed using a chemiluminescent immunometric assay (CLIA), and the serum level of dehydroepiandrosterone sulfate (DHEA-S) was analyzed using a chemiluminescence enzyme immunoassay (CLEIA). The serum level of N-terminal pro-B-type natriuretic peptide (NT-proBNP) was analyzed with an electrochemiluminescent immunoassay (ECLIA). The serum level of high-sensitivity C-reactive protein (hs-CRP) was analyzed using a latex nephelometric assay.

Urinary Adrenaline, Noradrenaline, and Dopamine Measurements

The levels of adrenaline, noradrenaline, and dopamine in urine were measured by an HPLC method using an HLC-725CAII analyzer. The instrument features a column-switching system composed of two pretreatment columns, a separation column and a high-sensitivity detection unit based on a post-column reaction using the fluorogenic reagent 1,2-diphenylethyleneamine. The detection limits of adrenaline, noradrenaline, and dopamine in urine were all 8 fmol/ml [1-4, 9].

Hematological Examinations

The white blood cell (WBC), red blood cell (RBC), and platelet (PLT) counts; the percentages of granulocytes, lymphocytes, and macrophages in the peripheral blood; and the concentration of hemoglobin (Hb), hematocrite (HCT), mean cell volume (MCV), mean cell hemoglobin (MCH), and mean cell hemoglobin concentration (MCHC) were determined using an automatic cell counter (LC-550, Horiba Co., LTD. Kyoto, Japan), as described previously [1-4, 9].

Statistical Analysis

Because blood pressure shows a circadian rhythm with different levels at different time points during the day; therefore, we could not compare blood pressure between 8:00 (before walking) and 13:00 (after walking), but could only compare blood pressure after walking in an urban setting with that after walking in forest environments at the same time point; i.e. urban vs. forest at 8:00 (before walking) or urban vs. forest at 13:00 (after walking).

From this perspective, paired t-tests should be used to compare the difference in blood pressure between urban and forest environments at the same time point. Thus, comparisons between different days were made with paired t-test. The analyses were performed with the Microsoft Excel software package for Windows. The significance level for p values was set at < 0.05.

Results

The weather during the trip to the forest park was excellent with temperatures ranging from 25.1-32.3, and humidity was 58%, and the weather during the visit to the urban area was also excellent with temperatures of 28.0-34.3 and humidity of 52%. The subjects consumed the same number of calories during the two trips. To control for the effects of alcohol, the subjects did not consume alcohol during the study period.

Caloric Consumptions

In the present study, caloric consumption was used to estimate the physical activity of the subjects. Caloric consumption was significantly greater during the walks in the urban area and the forest park than before the trips. However, there was no difference in caloric consumption between the two trips (Figure 1).

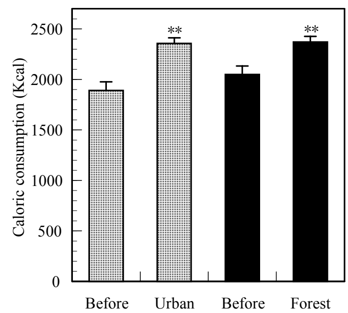

Figure 1. Caloric consumption during the experiments. Data are presented as the mean+SE (n=16). **: p<0.01, significantly different from the day before the walk in the urban area or the forest park according to the paired t-test. Cited from Li et al. Eur J Appl Physiol. 2011 Mar 23. [Epub ahead of print] with permission from Springer.

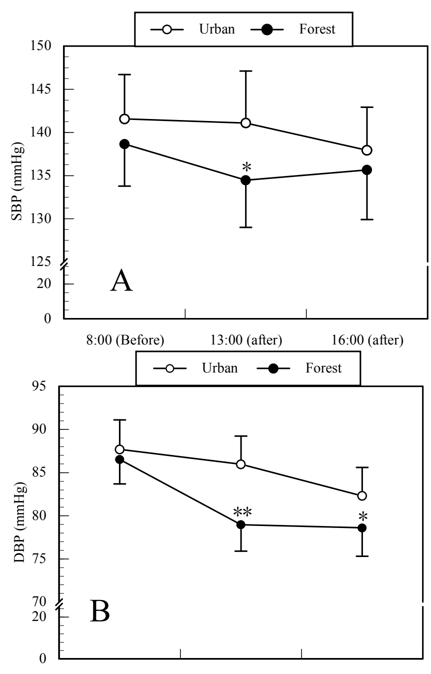

Figure 2. Effect of walking in a forest park and walking in an urban area on the levels of systolic (A) and diastolic (B) blood pressure. Data are presented as the mean+SE (n=16). *: p<0.05, **: p<0.01, significantly different between the forest and urban trips according to the paired t-test. Cited from Li et al. Eur J Appl Physiol. 2011 Mar 23. [Epub ahead of print] with permission from Springer.

Effect of Walking in Forest Environments on Blood Pressure

As shown in Figure 2, both systolic and diastolic blood pressure levels at noon (1300) in the forest park were significantly lower than those in the urban area. Moreover, the diastolic blood pressure level in the afternoon (1600) in the forest park was significantly lower than that in the urban area. However, there was no significant difference in both systolic and diastolic blood pressure levels before walking (0800) between the urban and forest. This suggests that walking in the forest park, but not in the urban area reduced blood pressure.

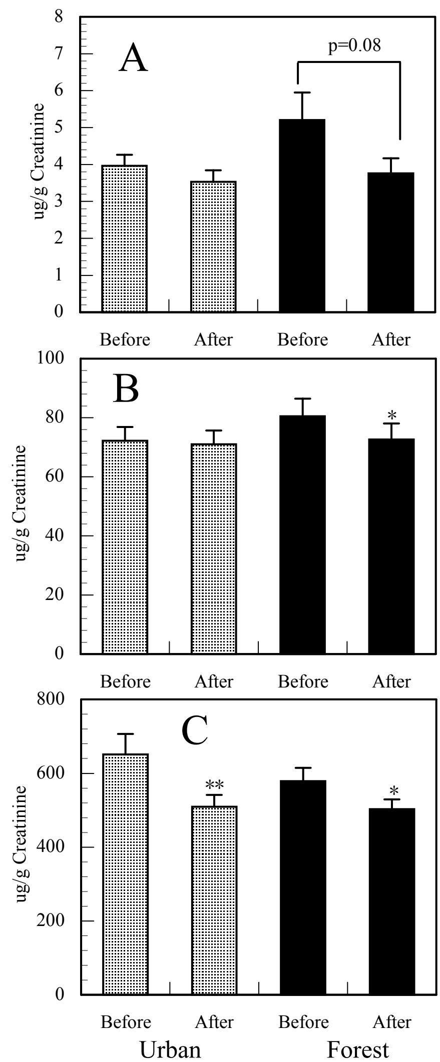

Figure 3. Effect of walking in a forest park and walking in an urban area on urinary adrenaline (A), noradrenaline (B), and dopamine concentrations (C). Data are presented as the mean+SE (n=16 for adrenaline and n=14 for noradrenaline and dopamine). *: p<0.05, **: p<0.01, significantly different between after and before according to the paired t-test. Cited from Li et al. Eur J Appl Physiol. 2011 Mar 23. [Epub ahead of print] with permission from Springer.

Effect of Walking in Forest Environments on Adrenaline, Noradrenaline, and Dopamine Concentrations in Urine

The concentrations of urinary noradrenaline and dopamine in two subjects before the forest park trip significantly exceeded the respective normal ranges (noradrenaline: subject 12: 346.0μg/l, subject 13: 973.4μg/l, normal range: 31-160μg/day; dopamine: subject 12: 2228.0μg/l, subject 13: 15624.3μg/l, normal range: 280-1100μg/day); therefore, the urinary noradrenaline and dopamine concentration data of these two subjects were excluded from the statistical analysis.

The level of urinary adrenaline tended to decrease after walking in the forest park although the difference was not significant (p=0.08, Figure 3A). On the other hand, walking in the forest environment significantly decreased the concentrations of noradrenaline and dopamine in urine, whereas walking in the urban area also significantly decreased the concentration of dopamine in urine (Figure 3C), but had no effect on urinary adrenaline or noradrenaline levels (Figure 3AB).

Effect of Walking in Forest Environments on Serum Adiponectin

As shown in Figure 4, walking in the forest park significantly increased the level of adiponectin in serum, but walking in the urban area did not affect the level of adiponectin, suggesting that forest environments affect serum adiponectin levels.

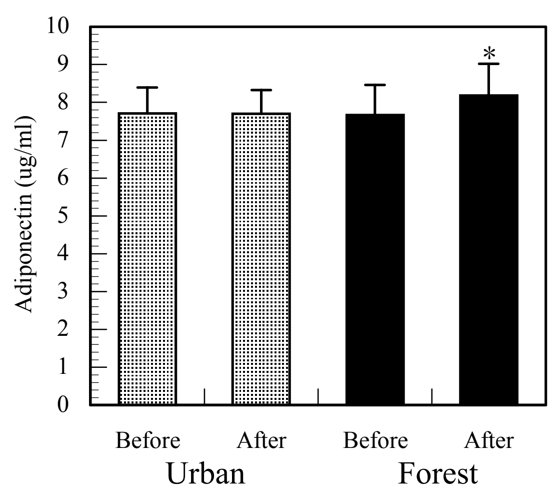

Figure 4. Effect of walking in a forest park and walking in an urban area on the serum adiponectin concentration. Data are presented as the mean+SE (n=16). *: p<0.05, significantly different between after and before the forest walk according to the paired t-test. Cited from Li et al. Eur J Appl Physiol. 2011 Mar 23. [Epub ahead of print] with permission from Springer.

Effect of Walking in Forest Environments on Serum DHEA-S

As shown in Figure 5, walking in the forest park significantly increased the serum level of DHEA-S, but walking in the urban area did not affect the serum level of DHEA-S, suggesting that forest environments may have a beneficial effect on the serum DHEA-S level.

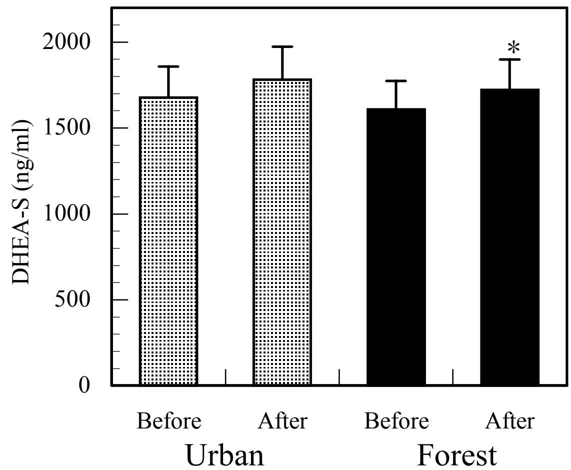

Figure 5. Effect of walking in a forest park and walking in an urban area on the serum DHEA-S concentration. Data are presented as the mean+SE (n=16). *: p<0.05, significantly different between after and before the forest walk according to the paired t-test. Cited from Li et al. Eur J Appl Physiol. 2011 Mar 23. [Epub ahead of print] with permission from Springer.

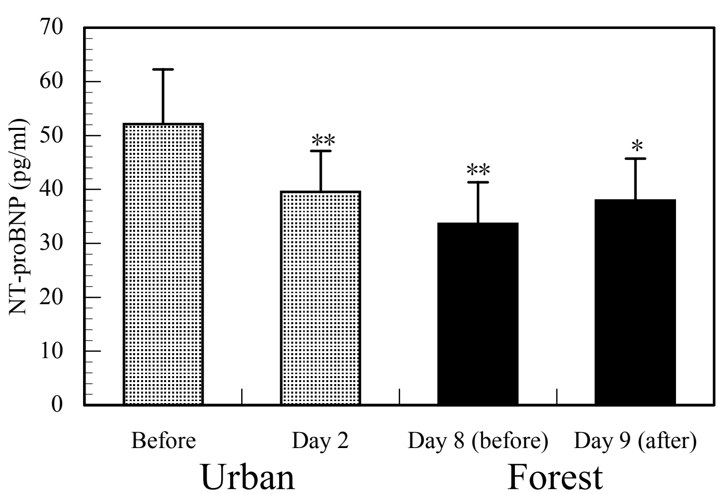

Figure 6. Effect of walking on the serum NT-proBNP concentration. Data are presented as the mean+SE (n=16). *: p<0.05, **: p<0.01, significantly different from before the walk in the urban area according to the paired t-test. Cited from Li et al. Eur J Appl Physiol. 2011 Mar 23. [Epub ahead of print] with permission from Springer.

Effect of Walking on Serum NT-proBNP

As shown in Figure 6, walking significantly decreased the serum NT-proBNP level, and this effect lasted for more than one week, suggesting that walking exercise has a beneficial effect on the serum NT-proBNP level.

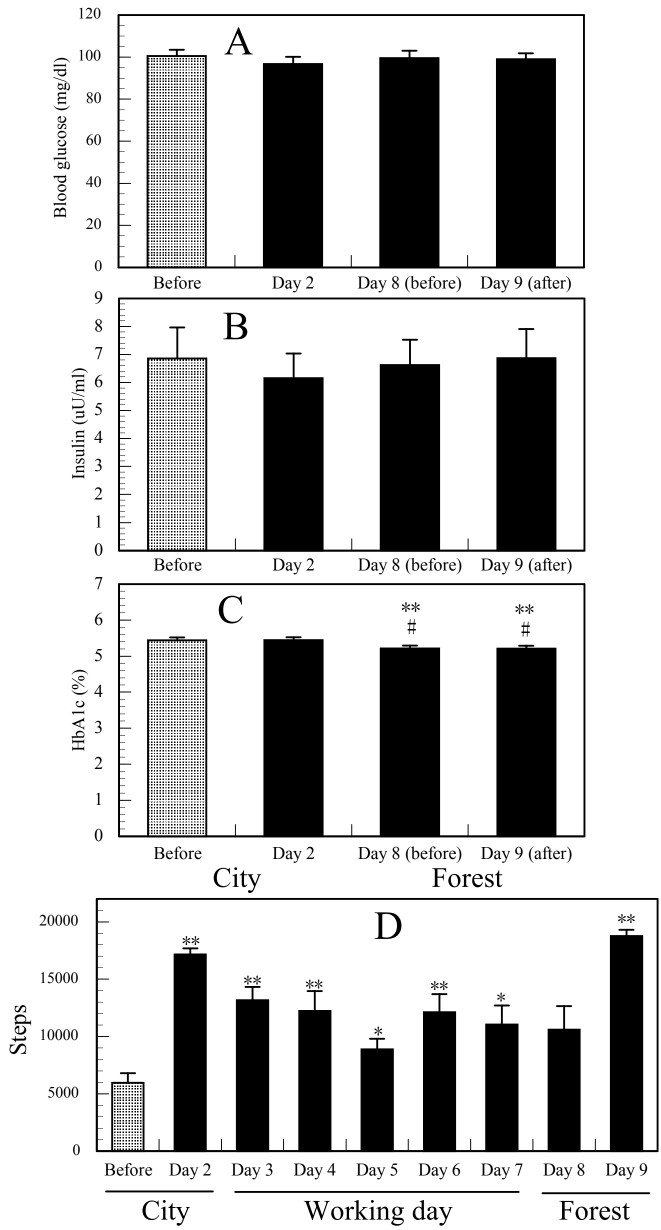

Figure 7. Effect of the walking in a forest park and walking in an urban area on the blood glucose (A), the levels of insulin (B) and the blood HbA1c concentration (C). (D): steps during the experiment. Data are presented as the mean+SE (n=16). **: p<0.05, **: p<0.01, significantly different from before the walking in city area (Before); #: p<0.01, significantly different from after the walking in city area (day 2) by paired t-test.

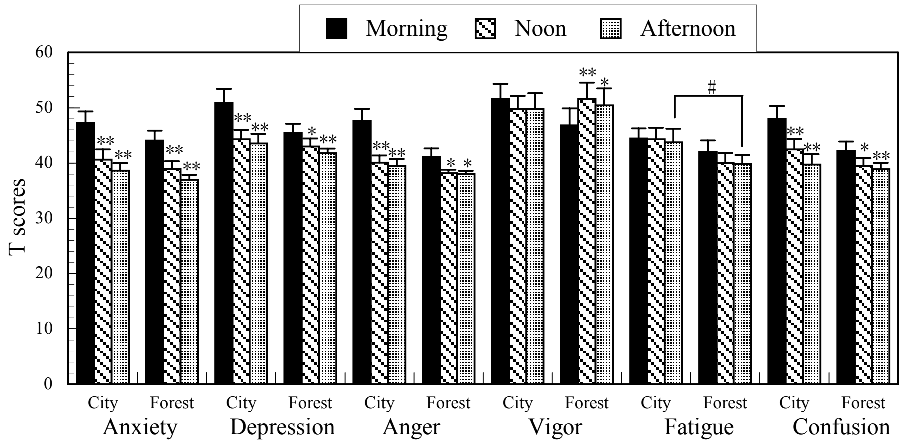

Figure 8. Effect of the walking in a forest park and walking in a city area on the POMS scores. Data are presented as the mean+SE (n=16). *: p<0.05, **: p<0.01, significantly different from the respective morning by paired t-test. #: p<0.05, significantly different between the city and forest by paired t-test.

Effect of Walking on Blood Glucose, Insulin and HbA1c

Neither walking in forest park nor walking in city area affected blood glucose and insulin level in serum (Figure 7AB). On the other hand, one week after the walking in city area, the blood HbA1c level (day 8) showed a significant decrease and this reduction was reproduced again on the next day (day 9), suggesting that physical activity (walking exercise) may have an effect on blood HbA1c level (Figure 7C). Figure 7D shows daily walking step during the experiment. The averaged steps of subjects during days 2-9 were 12997±3353 steps.

Effect of a Forest Bathing Trip versus a City Tourist Visit on POMS Test

Both trips significantly decreased the scores for anxiety, depression, anger, and confusion; however, only forest bathing trip significantly increased the score for vigor and decreased the scores for fatigue in POMS test (Figure 8).

Effect of Walking in the Forest Park on Lipid Metabolism and Other Parameters

As shown in Figure 9, neither walking in the forest park nor walking in the urban area affected the levels of triglycerides, total Cho, LDL-Cho, HDL-Cho, RLP-Cho, LDL (%), or IDL (%), RM (LDL), LPL, or hs-CRP in serum. On the other hand, walking in the urban area significantly increased VLDL (%) and decreased HDL (%).

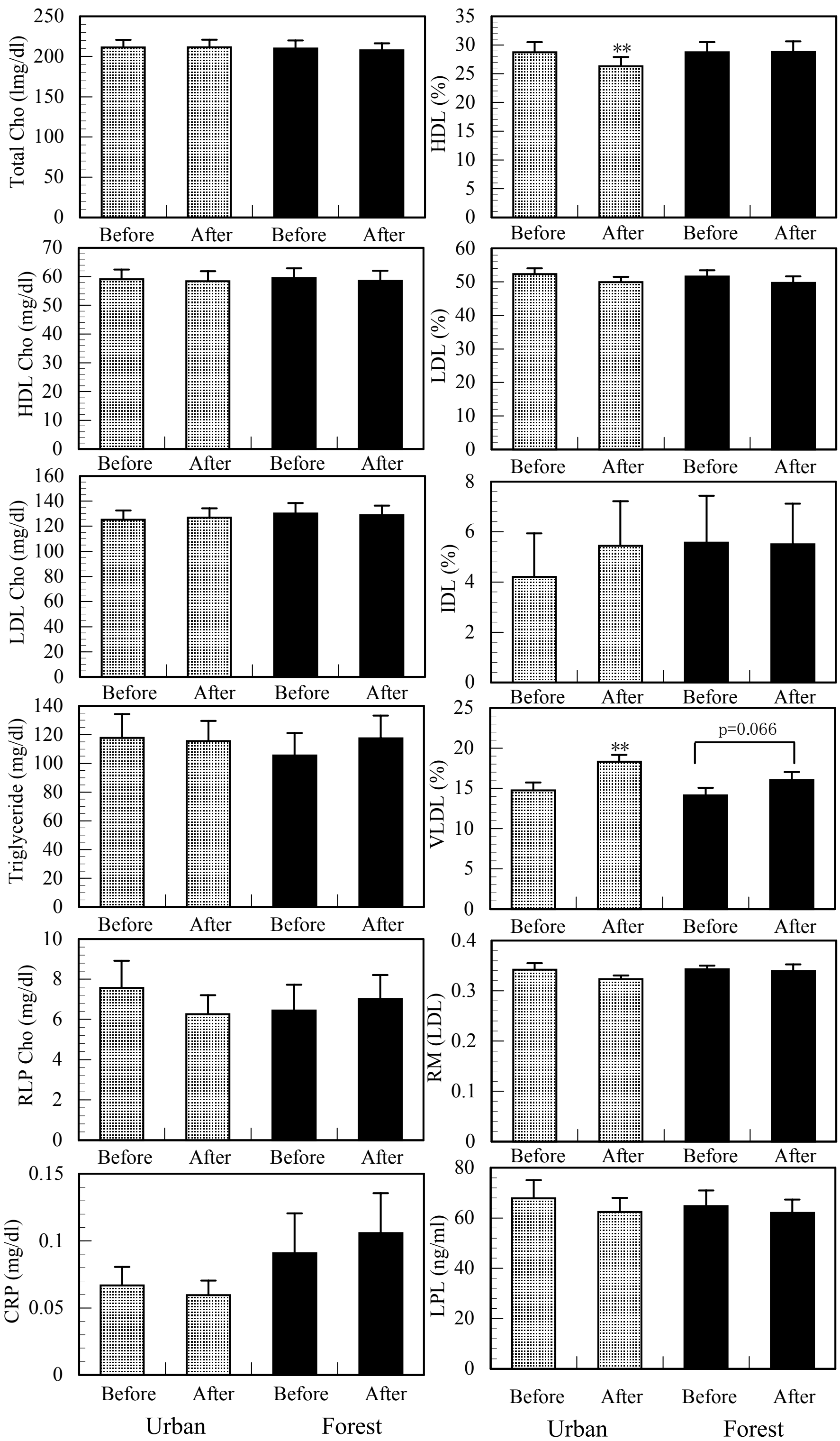

Figure 9. Effect of walking in the forest park on lipid metabolism and other parameters. Data are presented as the mean+SE (n=16). **: p<0.01, significantly different between after and before according to the paired t-test.

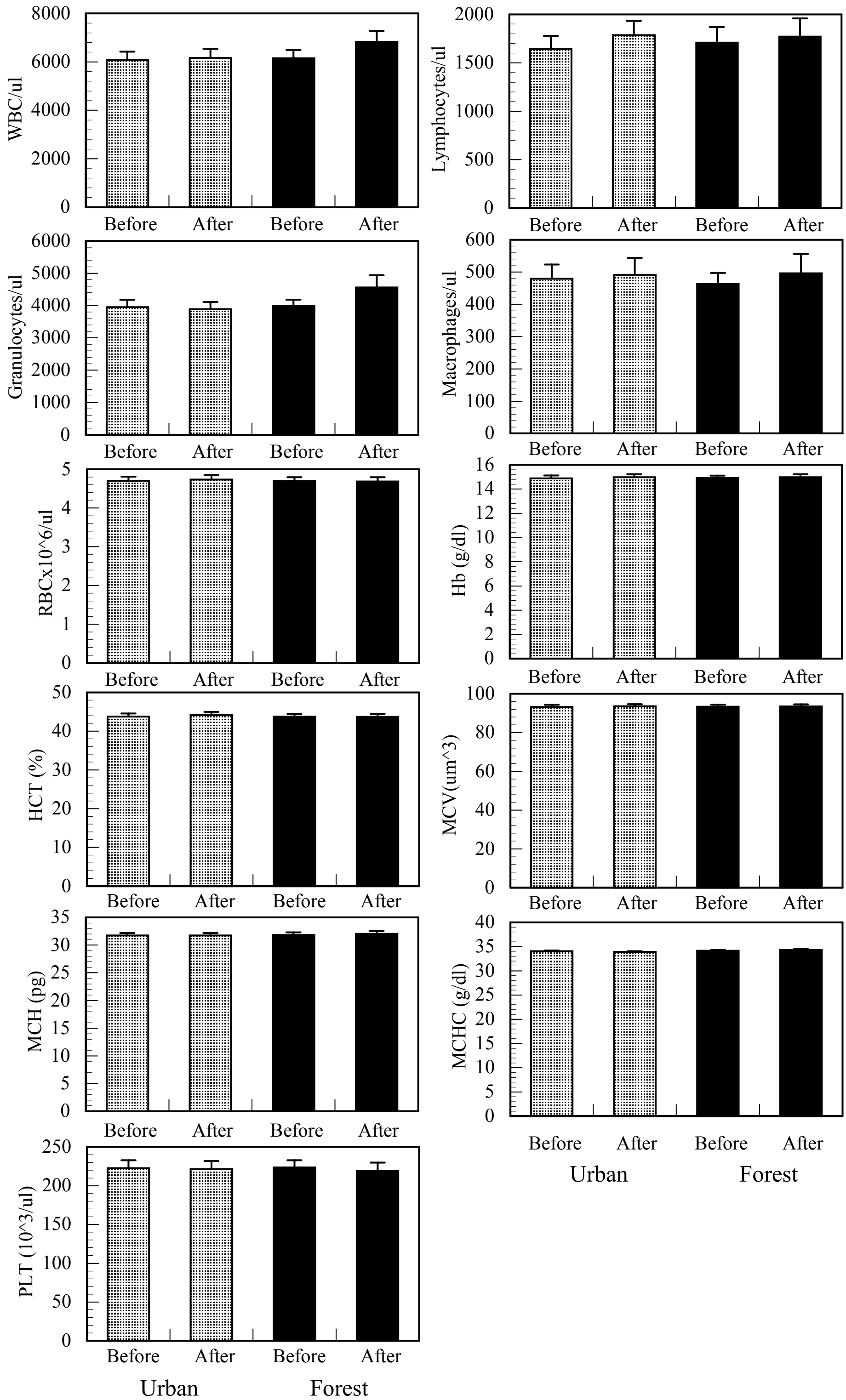

Figure 10. Effect of walking in the forest park on hematological parameters. Data are presented as the mean+SE (n=16).

Effect of Walking in the Forest Park on Hematological Parameters

As shown in Figure 10, neither walking in the forest park nor walking in the urban area affected the numbers of WBC, RBC, PLT, lymphocytes, granulocytes, or monocytes, the Hb concentration, HCT, MCV, MCH or MCHC in the peripheral blood.

There were no significant differences in the sleep durations of the subjects between before and after the forest park trip or the urban trip (data not shown).

Discussion

Because blood pressure shows a circadian rhythm with different levels at different time points during the day; therefore, we could not compare the blood pressure between 8:00 (before walking) and 13:00 (after walking), but could only compare blood pressure after walking in an urban setting with that after walking in forest environments at the same time point; i.e. urban vs. forest at 13:00 (after walking). In the present study, we found that walking in a forest park, but not in an urban area significantly reduced both systolic and diastolic blood pressure in male middle-aged subjects. It has been reported that habitual walking exercise for 4-58 weeks and physical activity have beneficial effects on lowering blood pressure [10-12]. However, there was no significant difference in physical activity between the walk in the forest park and that in the urban area, suggesting that the difference in blood pressure between the two trips was not due to physical activity. These findings suggest that habitual walking in forest environments has beneficial effects on lowering blood pressure. Park et al. [5] also reported that in young male students, walking in forest environments for about 20 min induced small, but significant decreases in both systolic and diastolic blood pressure compared to walking in urban areas, supporting our findings. However, there are many differences between our study and that by Park et al. [5]. First, the subjects were different: middle-aged subjects (36-77 years, mean±SD: 57.4±11.6) in our paper versus young male students (mean age ±SD: 21.7±1.5 years) in the study by Park et al. [5]. We consider that studying the effect of walking in forest environments on blood pressure in middle-aged subjects is more important than that in young male students. Second, the blood pressure levels of the subjects were different: higher levels of blood pressure (SBP: 141±19 and DBP: 87±11 mmHg) in our study versus lower levels of blood pressure (SBP: about 120-130 and DBP: about 60-70 mmHg) in the study by Park et al. [5]. It is generally accepted that studying the effect of walking in forest environments on blood pressure in subjects with a higher blood pressure is more important than that in those with a lower blood pressure. Finally, the reduction in blood pressure after walking in a forest environment was greater in our subjects (mean SBP: from 141 to 134 mmHg, mean DBP: from 86 to 79 mmHg) than in those studied by Park et al. [5] (the changes were very small).

Why do forest environments reduce blood pressure? To answer this question, we measured the levels of urinary adrenaline and noradrenaline in the present study and found that the urinary noradrenaline level after walking in the forest park was significantly decreased compared with that before the trip. In addition, the urinary adrenaline level also tended to decrease after walking in the forest park. It is well known that the sympathetic and parasympathetic nerve systems play a pivotal role in the regulation of blood pressure and that sympathetic nerve activity increases blood pressure, whereas parasympathetic nerve activity reduces blood pressure [13]. Sympathetic nerve activity can be determined by measuring the levels of urinary adrenaline and/or noradrenaline [14], and there are significant correlations between blood pressure and urinary adrenaline and noradrenaline levels [13]. We previously found that walking in forest environments, but not urban environments reduced the urinary levels of adrenaline and/or noradrenaline in both male and female subjects [2-4]. In addition, Park et al. [5] reported that forest viewing and walking significantly reduced sympathetic nerve activity and increased parasympathetic nerve activity compared to performing the same activities in an urban environment, supporting our findings. Taken together, walking in forest environments may reduce blood pressure by lowering the activity of the sympathetic nerve and increasing the activity of the parasympathetic nerve.

Why factors in forest environments reduce blood pressure? We speculated that phytoncides (wood essential oils) from trees may have beneficial effects on blood pressure. Dayawansa et al. [15] reported that cedrol (cedar wood oil) inhalation induced significant reductions in systolic and diastolic blood pressure compared to blank air together with an increase in parasympathetic activity and a reduction in sympathetic activity in humans. We previously found that exposure to a tree-derived phytoncide (Chamaecyparis obtusa stem oil) by inhalation significantly reduced the concentrations of urinary adrenaline and noradrenaline in males [9]. In fact, phytoncides, such as alpha-pinene, beta-pinene, tricyclene, camphene, and limonene, were detected in higher concentrations in the forest park, but were not detected in the urban area of Tokyo [4]. Taken together, the above findings suggest that the natural fragrance of trees (phytoncides) partially contributed to the reduction in blood pressure observed during walking in the forest park in the present study.

Adiponectin (also called ARCP30 and AdipoQ) is a serum protein hormone that is specifically produced by adipose tissue. Studies have shown that lower than normal blood adiponectin concentrations are associated with several metabolic disorders, including obesity, type 2 diabetes mellitus, cardiovascular disease, and metabolic syndrome [16]. In the present study, we found that walking in a forest park, but not an urban area significantly increased the level of blood adiponectin, suggesting that habitual walking in forest environments may have a beneficial effect on blood adiponectin levels. Previous studies on the effects of acute exercise on adiponectin levels have shown discrepancies. A systematic review of the effects of exercise on adiponectin level identified seven acute exposure exercise studies with conflicting findings [16]. Some studies have shown no effect of acute exercise on adiponectin levels in normal or overweight individuals [17-19], but other studies have observed significant changes in adiponectin levels [20, 21]. Chang et al. [22] found that 60-min Yang's style Tai Chi exercise significantly increased the blood adiponectin levels of the middle-aged subjects (mean age: 60.2 years). In the present study, there was no significant difference in physical activity between the walk in the forest park and that in the urban area suggesting that the differences in blood adiponectin levels between the two trips were not due to physical activity. Taken together, the above findings suggest that both walking (exercise) and the forest environment contributed to the increase in blood adiponectin seen in this study. However, further studies are necessary to explore why the forest environment increased the level of blood adiponectin.

The levels of DHEA and DHEA-S, the major secretory products of the adrenal gland, decline dramatically with age, concurrent with the onset of degenerative changes and chronic diseases associated with aging [23, 24]. Epidemiological evidence in humans suggests that DHEA-S has cardioprotective, antiobesity, and antidiabetic properties [23]. In the present study, we found that walking in a forest park significantly increased the blood level of DHEA-S. Although walking in an urban area also increased the blood level of DHEA-S the increase was not significant, suggesting that habitual walking in forest environments has beneficial effects on blood DHEA-S. In males, it has been shown that acute exercise induces an increase in circulating DHEA-S level. Such changes are directly related to the type of exercise, its intensity and duration, and to the subject's training status [25]. On the other hand, Tsai et al. [24] reported that resistance exercise induced a significant decrease at post-48h and post-72h. In the present study, there was no significant difference in physical activity between walk in the forest park and that in the urban area suggesting that the difference in serum DHEA-S between the two trips was not due to physical activity. Antoni [26] reported that a cognitive behavioral stress management intervention induced a reduction in urinary noradrenaline level (and reduced anxiety) and an increase in serum DHEA-S levels (and a reduced incidence of depressed moods). We also found that the increase in blood DHEA-S levels observed after the walk in the forest park was accompanied by a reduction in urinary noradrenaline levels in the present study. Moreover, Brzoza et al. [27] reported that the DHEA-S concentration is negatively correlated with the level of anxiety and the level of depression in chronic urticaria patients and that the DHEA-S reductions observed in chronic urticaria patients might be a phenomenon secondary to psychological disturbance. Taken together, the above findings suggest that stress status affects the serum level of DHEA-S.

Measurements of the circulating concentration of NT-proBNP, a cardiac biomarker, are used to diagnose heart failure and left ventricular dysfunction [28]. Increased NT-proBNP levels are independently associated with an increased risk of death and heart failure progression in several disorders, including chronic heart failure, acute coronary syndromes, and processes involving the right ventricle [29]. In the present study, on the day before the urban area trip, the mean number of steps taken by the subjects was 5951±3341, whereas on the walking day, it was 17156±2074, which was significantly greater than that before the walking day. The serum NT-proBNP level after the walking (39.6±29.3 pg/ml, day 2) was significantly decreased compared with that before the walking (52.1±39.4 pg/ml), and this effect lasted for more than one week (33.6±30.0 pg/ml on day 8 and 38.0±30.0 pg/ml on day 9 after the walking), suggesting that habitual walking exercise has beneficial effects on the circulating concentration of NT-proBNP. On the other hand, there was no significant difference in blood pressure between before (142±20/88±13 mmHg) and after (141±19/87±11 mmHg) the walking, suggesting that the change in the serum NT-proBNP level was independent of the change in blood pressure. Berent et al. [30] reported that four weeks of moderate exercise reduced the NT-proBNP level, independent of the left ventricular ejection fraction, and improved physical fitness and blood lipid profiles. Physical training of moderate intensity significantly improves exercise capacity and reduces the serum level of NT pro-BNP in patients with chronic heart failure [31]. In addition, the blood NT-proBNP level of athletes was significantly lower than that of sedentary controls [32]. On the other hand, intense exercises such as running a marathon significantly increased the blood NT-pro-BNP concentration [33, 34], suggesting that the intensity of exercise affects the serum level of NT-pro-BNP.

Although neither walking in forest park nor walking in city area affected blood glucose (Figure 7A) and insulin level in serum (Figure 7B), the blood HbA1c level on day 8 (Figure 7C) showed a significant decrease after one week daily walking with 12997±3353 steps (Figure 7D) and this reduction was reproduced again on the next day (day 9), suggesting that physical activity (walking exercise) may have a beneficial effect on blood HbA1c level. It has been reported that walking exercise for 1 month [35], 8 weeks [36, 37], 3 months and more [38] significantly reduced the blood HbA1c level in type-2 diabetes patients, respectively. However, there has been no report dealt with the effect of walking exercise with short-term (one week) on blood HbA1c level.

In addition, both trips significantly decreased the scores for anxiety, depression, anger, and confusion; however, only forest bathing trip increased the score for vigor and decreased the scores for fatigue in POMS test, confirming the previous findings [1, 3, 4].

As a limitation, the present study only showed the acute effects of walking in forest environments; therefore, a further study is necessary to investigate the chronic effects of walking in forest environments with longer-term and repeat studies.

In conclusion, habitual walking in forest environments may lower blood pressure by reducing sympathetic nerve activity (reducing urinary noradrenaline levels) and increasing parasympathetic nerve activity. In addition, habitual walking in forest environments may have beneficial effects on blood adiponectin and DHEA-S levels, and habitual walking exercise may have beneficial effects on blood NT-proBNP levels.

Conflict of Interest Statements

None declared.

Acknowledgments

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Chapter 11

Effect of Forest Environments on Psychological Response Evaluated by the POMS Test

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Abstract

Objectives: We used the POMS test to investigate the psychological effects of trips to a forest in both males and females.

Methods: Three experiments were conducted. 1) Twelve healthy male subjects, aged 37-55 years, and 13 healthy female subjects, aged 25-43 years, experienced a three-day/two-night trip to forest fields. On day 1, subjects walked for two hours in the afternoon in a field; and on day 2, they walked for two hours each in the morning and afternoon, at two different fields. 2) Sixteen healthy males, aged 36-77 years, experienced day trips to an urban area and a forest park in the suburbs of Tokyo. They walked for two hours each in the morning and afternoon, in the forest park/ urban area on a Sunday. 3) 53 and 98 subjects experienced a 2-hour walk in a forest field and a city park, respectively. The POMS test was conducted before, during, and after the trip/walk.

Results: The three-day excursion significantly increased the score for vigor and decreased the scores for anxiety, depression and anger in males; and significantly increased the score for vigor and decreased the scores for anxiety, depression, anger, fatigue, and confusion in females. The day trip to the forest park or urban area also significantly decreased the scores for anxiety, depression, anger, and confusion; however, only the trip to the forest park significantly increased the score for vigor and decreased the scores for fatigue in male subjects. The 2-hour walk in a city park with a good density of trees or in a forest field also significantly increased the score for vigor and decreased

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the scores for anxiety, depression, anger, fatigue, and confusion in both male and female subjects.

Conclusions: Walking significantly decreased the scores for anxiety, depression, anger, fatigue and confusion; however only walking in forest fields, not in a city area, significantly increased the score for vigor.

Keywords: forest bathing, park, POMS, walking

Introduction

A forest bathing trip, called "Shinrinyoku" in Japanese, involves a visit to a forest field for the purpose of relaxation and recreation by breathing in volatile substances, called phytocides, released from trees [1-7]. It was first proposed in the 1980s and has become a recognized relaxation activity in Japan [1-11]. Since forests occupy 67% Japan [12-13], they are readily accessible. According to a public opinion poll conducted in 2003, 25.6% of respondents had participated in a forest trip, indicating its popularity in Japan [10]. Moreover, forest bathing is possible throughout much of the world. Forest environments may reduce stress and have relaxing effects. The Profile of Mood States (POMS) test, developed by McNair et al. [14], is a 65-item self-administered questionnaire designed to assess six mood states; tension-anxiety, anger-hostility, fatigue, depression, vigor and confusion. Yokoyama et al. [15] developed a Japanese version and reported acceptable levels of reliability and validity. The POMS test has been used to evaluate the effects of exercise [16]. Thus, in the present study, it was used to evaluate the effects of forest bathing trips in both male and female subjects.

Effect of a Three-Day/Two-Night Forest Bathing Trip on POMS Scores in Male Subjects

In this experiment, twelve healthy males, aged 37-55 years (mean±SD: 43.1±6.1), experienced a three-day/two-night trip at forest fields. On day 1, the subjects walked for about 2.5km over two hours in the afternoon in a forest field; and on day 2, they walked for two hours each in the morning and afternoon in two different fields for about 5 km. The information gathered from the self-administered questionnaire, including on age and cigarette smoking, alcohol consumption, eating breakfast, sleeping hours, working hours, physical exercise, nutritional balance and mental stress, has been reported previously [17]. Written informed consent was obtained from all subjects after a full explanation of the study procedures. The ethics committee of the Nippon Medical School approved this study. The Japanese version of the POMS test was conducted before, during, and after the trips [15].

As shown in Figure 1, the forest bathing trip significantly increased the score for vigor and decreased the scores for anxiety, depression and anger in male subjects. There was no significant change in the score for fatigue or confusion [1].

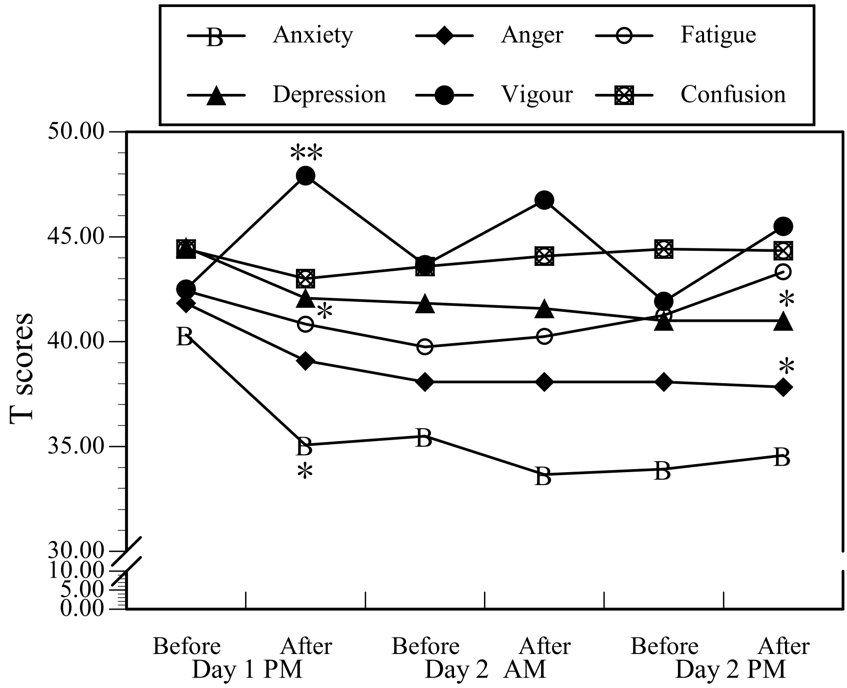

Figure 1. Effect of a three-day/two-night forest bathing trip on POMS scores in male subjects. Data are presented as the means (n=12).*: p<0.05, **: p<0.01, significantly different from before the trip on Day 1 pm by the paired t-test. Cited from Li et al. Int J Immunopathol Pharmacol. 2007;20:3-8 with permission from Biolife.

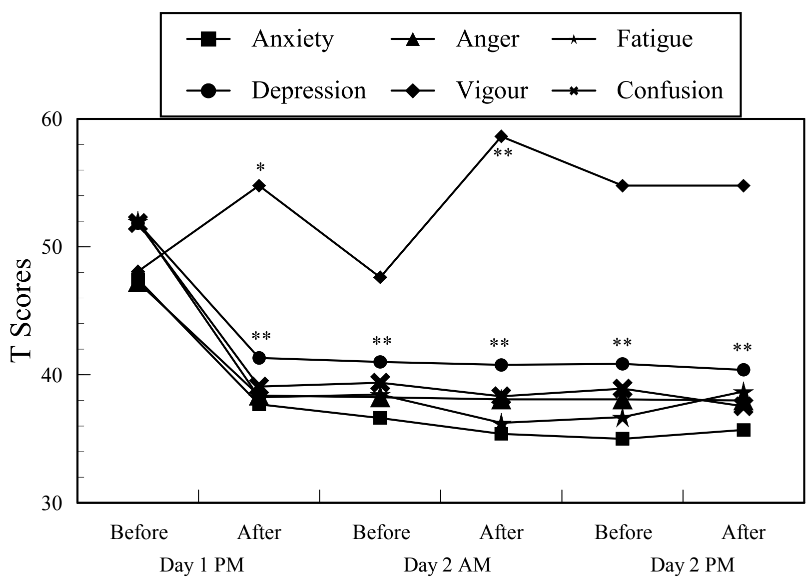

Figure 2. Effect of a three-day/two-night forest bathing trip on POMS scores in female subjects. Data are presented as the mean (n=13). *: p<0.05, **: p<0.01, significantly different from before the trip on

Day 1 pm by paired t-test (anxiety, depression, anger, fatigue, and confusion). Cited from Li et al. J Biol Regul Homeost Agents. 2008;22:45-55 with permission from Biolife.

Effect of a Three-Day Forest Bathing Trip on POMS Scores in Female Subjects

In this experiment, 13 healthy females, aged 25-43 years (mean±SD: 28.8±4.6), experienced a three-day trip in forest fields. On day 1, subjects walked for about 2.5km over two hours in the afternoon in a forest field; and on day 2, they walked for two hours each in the morning and afternoon in two different fields for about 5 km. The POMS test was conducted before, during and after the trip [15].

As shown in figure 2, the trip significantly increased the score for vigor and decreased the scores for anxiety, depression, anger, fatigue, and confusion [3].

Effect of Walking in a Forest Park and Walking in an Urban Area on POMS Scores

In this experiment, 16 healthy males, aged 36-77 years (mean±SD: 57.4±11.6) experienced day trips to an urban area or a forest park in the suburbs of Tokyo. They walked for two hours each in the morning and afternoon in a forest park/urban area for about 6 km on a Sunday [7]. The POMS test was conducted before, during and after the trip [15].

As shown in figure 3, both trips significantly decreased the scores for anxiety, depression, anger, and confusion; however, only the forest bathing trip significantly increased the score for vigor and decreased the score for fatigue in male subjects.

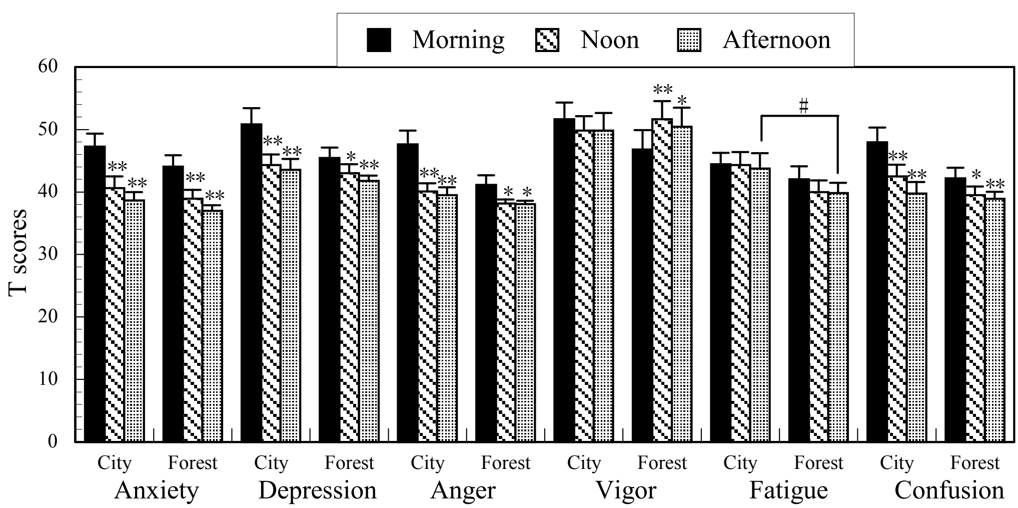

Figure 3. Effect of walking in a forest park and walking in an urban area without trees on the POMS scores. Data are presented as the mean+SE (n=16). *: p<0.05, **: p<0.01, significantly different from the respective morning by paired t-test. #: p<0.05, significantly different between the urban area and forest by paired t-test.

Effect of a 2-Hour Walk in a Forest Field on POMS Scores in Male and Female Subjects

In this experiment, 52 subjects, aged 26-78 years (mean±SD: 57.0±12.9) took a 2-hour walk covering about 2.5 km in a forest field. The POMS test was conducted before and after the walk [15].

As shown in Figure 4, the walk significantly increased the score for vigor in females (Figure 4B) and decreased the scores for anxiety, depression, anger, fatigue and confusion in both males (Figure 4A) and females. There was a significant difference in the change in the score for vigor between males and females (Figure 4C).

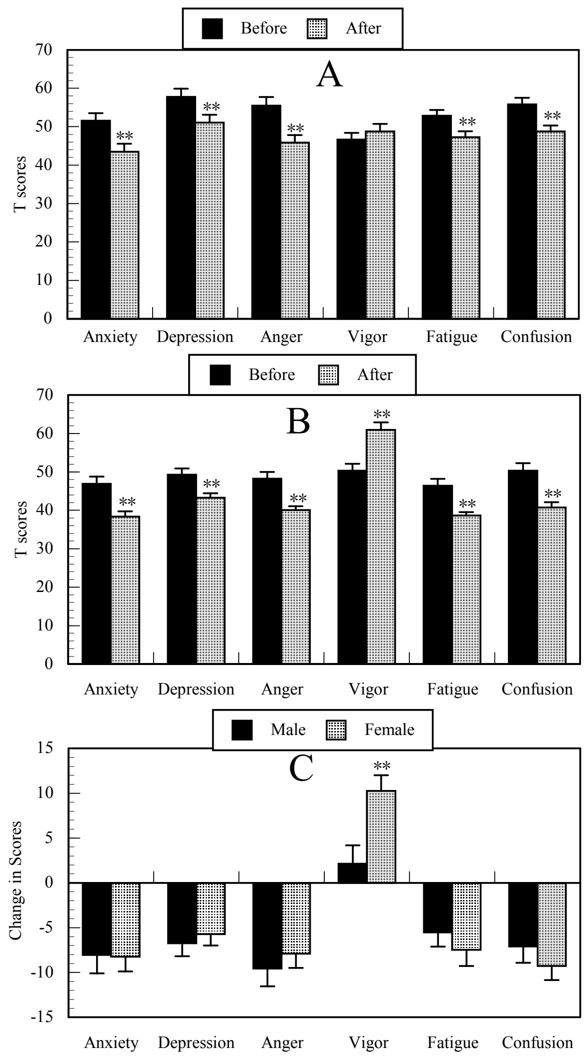

Figure 4. Effect of a 2-hour walk in a forest field on POMS scores in male (A) and female (B) subjects; (C): changes in scores after the walk in male and female subjects. Data are presented as the mean+SE (n=23 for males and n=29 for females). **: p<0.01, significantly different between before and after the walk (A, B) by the paired t-test or between male and female (C) by the unpaired t-test.

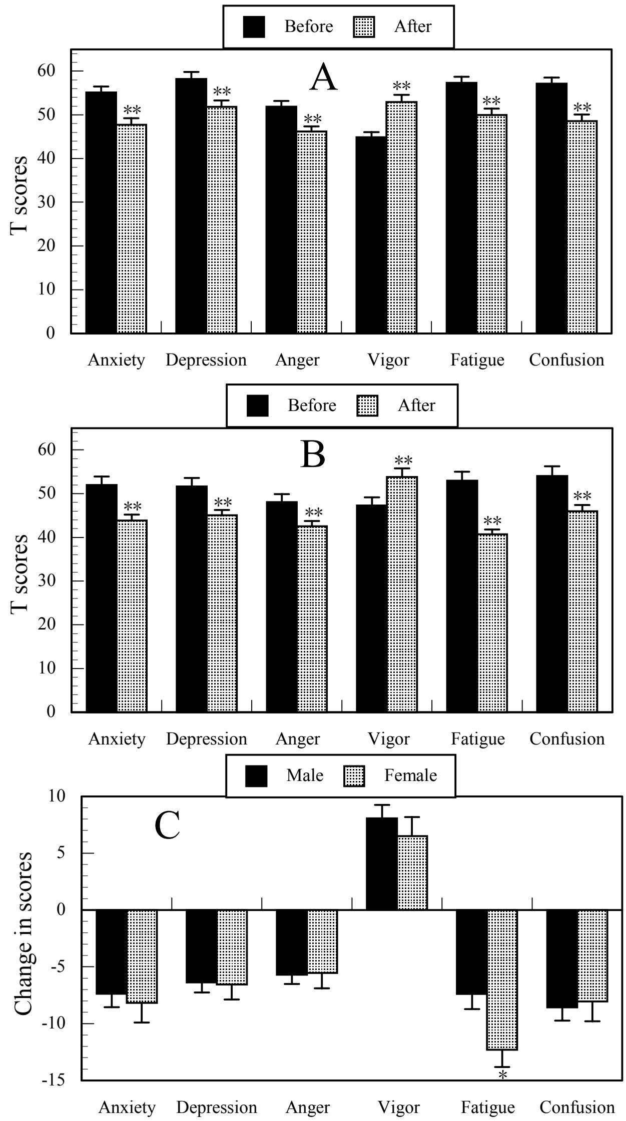

Figure 5. Effect of a 2-hour walk in a city park with a good density of trees on POMS scores in male (A) and female (B) college students; (C): changes in scores after the walk in male and female subjects. Data are presented as the mean+SE (n=68 for males and n=30 for females). *: $p<0.05$, **: $p<0.01$, significantly different between before and after the walk (A, B) by the paired t-test or between male and female (C) by the unpaired t-test.

Effect of a 2-Hour Walk in a City Park on POMS Scores in College Students

In this experiment, 98 subjects, aged 20-47 years (mean±SD: 22.6±3.2) took a 2-hour walk covering about 2.5 km in a city park with a good density of trees in Tokyo. The POMS test was conducted before and after the walk [15]. As shown in figure 5, the walk significantly increased the score for vigor and decreased the scores for anxiety, depression, anger, fatigue and confusion in both male (Figure 5A) and female (Figure 5B) subjects. There was a significant difference in the change in the score for fatigue between males and females (Figure 5C).

Discussion

The POMS test, developed by McNair et al. [14], is a 65-item self-administered questionnaire designed to assess six mood states; tension-anxiety, anger-hostility, fatigue, depression, vigor and confusion. Yokoyama et al. [15] developed a Japanese version and reported acceptable levels of reliability and validity. The POMS test has been widely used to evaluate stress status and stress management [18], relaxation effects of exercise [16], and mood states in psychiatric outpatients [19]. To evaluate the influence of forest environments, we first investigated the effect of a three-day/two-night forest bathing trip on the psychological response of male subjects and found that the trip significantly increased the score for vigor and decreased the scores for anxiety, depression and anger, without significantly changing the scores for fatigue and confusion [1]. Nevertheless, whether forest bathing trips have the same effect in females remained to be clarified. Thus, we conducted a second experiment to investigate the effect of a three-day/two-night trip on the psychological response of female subjects. It was found that the forest bathing trip significantly increased the score for vigor and decreased the scores for anxiety, depression, anger, fatigue, and confusion accompanied by reductions in urinary adrenaline and noradrenaline concentrations [3]. These findings suggest that forest bathing trips indeed have relaxing effects and that the effects on fatigue and confusion are greater in females than males. Although the three-day/two-night trip produced beneficial effects, it is not clear whether a day trip to a forest park would have the same effect. Thus, in the third experiment, we investigated the effects of a day trip to a forest park in male subjects and found that it significantly increased the score for vigor and significantly decreased the scores for anxiety, depression, anger, and confusion accompanied by a reduction in urinary noradrenaline level [7], suggesting the day trip to have a similar relaxing effect to the three-day trip. However, it is not clear whether the effects were due to walking or to the forest environment. Thus, we conducted a day trip to an urban area to investigate the effect of walking on mood states. It was found that walking in an urban area also significantly decreased the scores for anxiety, depression, anger, and confusion, but had no effect on vigor or fatigue. These findings indicate that both environments contributed to the reductions in the scores for anxiety, depression, anger, and confusion; however, only the forest had a positive effect on vigor and fatigue.

To investigate whether a shorter stay in a forest (e.g. a half day trip) has a similar relaxing effect, we conducted an experiment with a 2-hour walk in a forest field. The walk significantly increased the score for vigor in females and decreased the scores for anxiety, depression, anger, fatigue and confusion in both males and females, suggesting that a 2-hour excursion has a similar relaxing effect to longer trips and that females are affected more than males. Moreover, to investigate whether a city park with a good density of trees also has a relaxing effect, an experiment with a 2-hour walk in a park in Tokyo was conducted. The walk significantly increased the score for vigor and decreased the scores for anxiety, depression, anger, fatigue and confusion in both males and females, but had more of an effect on fatigue in females. Taken together, because the three-day trip, day trip and 2-hour walk all had similar relaxation effects, the period spent in the forest setting did not affect the results and a 2-hour walk was sufficient to obtain an effect. In addition, females showed more of an effect than males. Park et al. [11] also reported that walking in a forest significantly increased the score for vigor and decreased the scores for anxiety, depression, anger, fatigue and confusion accompanied by reductions in sympathetic nerve activity and increases in parasympathetic nerve activity compared to walking in a city environment in male subjects. Morita et al. [10] used the Multiple Mood Scale-Short Form (hostility, depression, boredom, friendliness, wellbeing and liveliness) to investigate the effect of a trip to a forest and found that hostility and depression scores decreased significantly, and liveliness scores increased significantly on the forest day compared with the control day. They concluded that customary forest bathing may help to decrease the risk of psychosocial stress-related diseases.

What factors in the forest environment improved mood? The quiet atmosphere, beautiful scenery, mild climate, and fresh, clean air in forests may have beneficial effects on mood states. As an olfactory factor, phytoncides (essential oils) from trees may have positive effects as well. Schiffman et al. [20] reported that pleasant odors improved the mood of middle-aged males. Both jasmine tea and lavender odors produced calm and vigorous moods [21]. Aromatherapy-massage with essential oils significantly increased the score for vigor in the POMS test [22]. We previously found that exposure to phytoncides through inhalation had a relaxing effect in male subjects [23]. In fact, several phytoncides, such as alpha-pinene, beta-pinene, isoprene and limonene, were detected in the forest fields and forest park during the trips [1-4], suggesting that phytoncides from trees may partially contribute to the relaxing effects. In addition, Park et al. [11] reported that forest viewing significantly increased the score for vigor and decreased the scores for anxiety, depression, anger, fatigue and confusion accompanied by reductions in sympathetic nerve activity and increases in parasympathetic nerve activity, suggesting that visual factors (the scenery, green coloring) also contribute to the relaxing effects.

In summary, forest bathing trips significantly increased the score for vigor and decreased the scores for anxiety, depression, anger, fatigue and confusion in the POMS test and produced relaxing effects. The duration of stay in the forest did not influence the relaxing effects and a 2-hour walk is sufficient to obtain an effect.

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Chapter 12

Effect of the Forest Environment on the Human Psycho-Neuro-Endocrino-Immune Network

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Abstract

Traditional thinking considered the nervous system, endocrine system and immune system to be independent of each other. However, it is now widely accepted that they interact through the psycho-neuro-endocrino-immune network. The nervous system affects the endocrine and immune systems by releasing neurotransmitters through the hypothalamus in the hypothalamic-pituitary portal circulation. The endocrine system affects the nervous and immune systems by secreting hormones and the immune system feeds back to the nervous and endocrine systems via cytokines. This chapter will review the effects of forest environments on the human psycho-neuro-endocrino-immune network.

Keywords: endocrine system, forest environment, immune system, nervous system, psycho-neuro-endocrino-immune network

Introduction

The nervous system, endocrine system and immune system had been considered independent entities. However, it is now widely accepted that the activation of peripheral immune cells results in changes of brain function. Conversely, the activation of certain brain neurons results in immunoregulatory neuro-endocrine responses. Recent evidence indicates

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that brain-borne cytokines, such as IL-1 and IL-6, mediate to a large extent such reciprocal effects [1].

The central nervous system has direct endocrine activity or controls endocrine cells: it releases neurotransmitters through the hypothalamus in the hypothalamic-pituitary portal circulation. Neurotransmitters regulate the secretory activity of the anterior pituitary gland and, eventually, of endocrine glands throughout the body via the hypothalamic–pituitary–adrenal (HPA) axis.

The adrenal medulla releases epinephrine and norepinephrine into the bloodstream, which contribute to the systemic regulation of immune function [2, 3]. On the other hand, immune cells release cytokines, which, in turn signal to the central and peripheral nervous system [4].

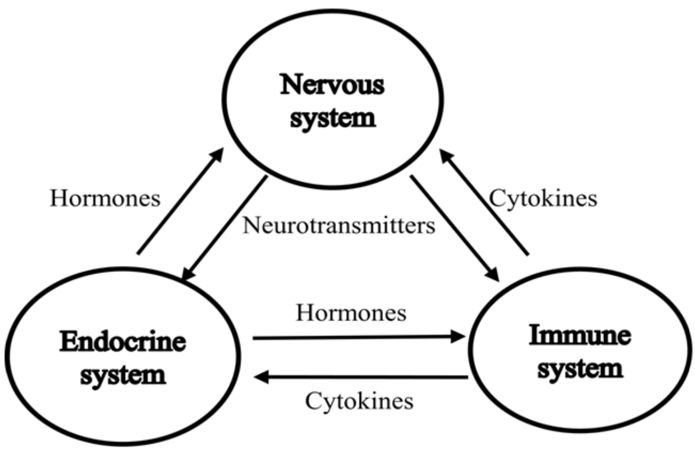

Figure 1. The psycho-neuro-endocrino-immune network.

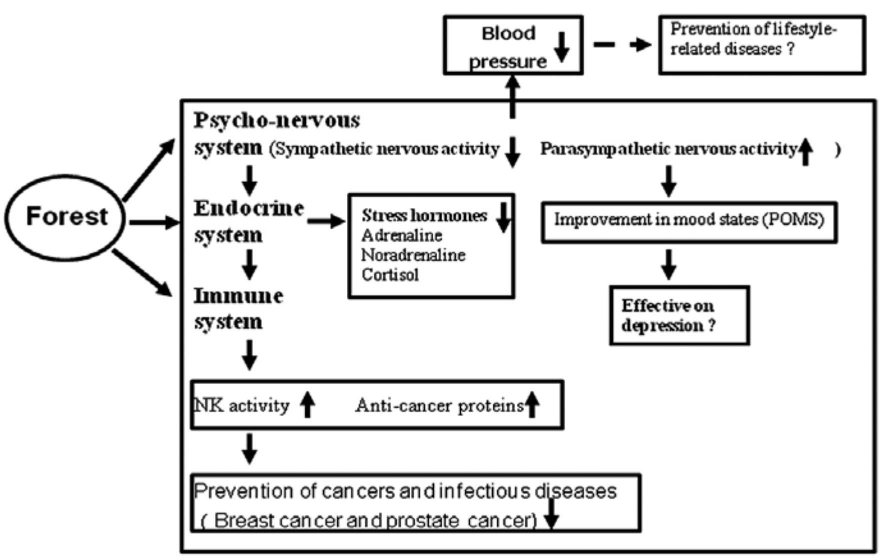

Figure 2. Effect of the forest environment on the psycho-neuro-endocrino-immune network.

In addition, some cytokines initially conceived as immune products, such as IL-1 and IL-6, are also produced in the "healthy" brain by glial cells and even by some neurons [1]. Taken together, the nervous system affects the endocrine and immune systems by releasing neurotransmitters through the hypothalamus in the hypothalamic-pituitary portal circulation.

On the other hand, the endocrine system affects the nervous and immune systems by secreting hormones. Moreover, the immune system feeds back to the nervous and endocrine systems through cytokines such as IL-1 and IL-6 (Figure 1). Forest environments (forest bathing) produce various effects on human health through the psycho-neuro-endocrino-immune network (Figure 2).

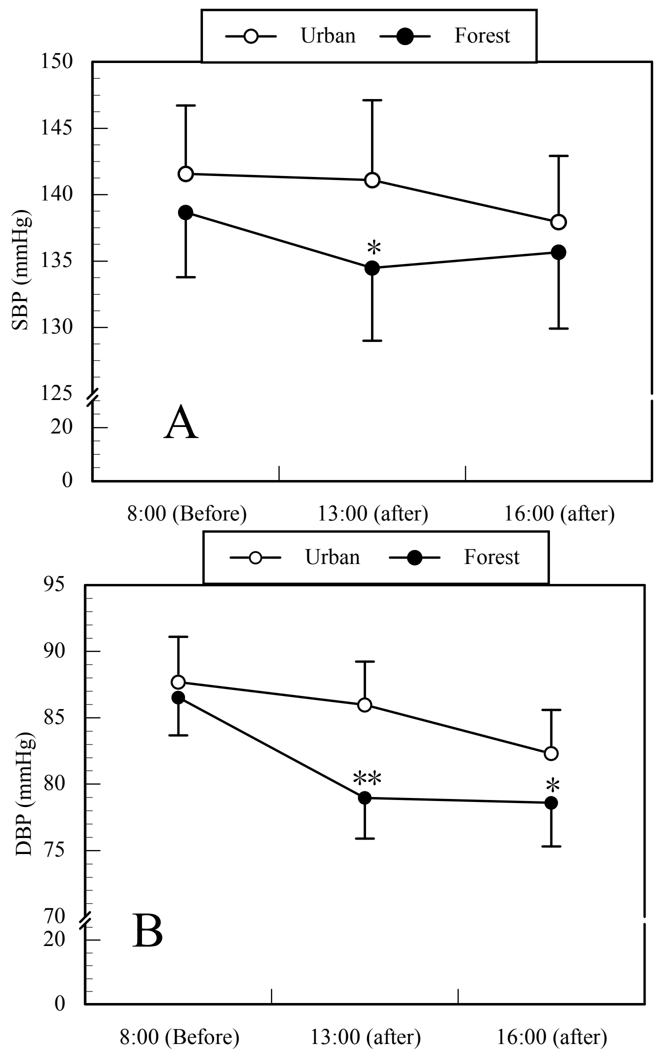

Figure 3. Effect of walking in a forest park and walking in an urban area on systolic (A) and diastolic (B) blood pressure. Data are presented as the mean+SE (n=16). *: $p<0.05$, **: $p<0.01$, significantly different between the forest and urban trips according to the paired t-test. Cited from Li et al. Eur J Appl Physiol. 2011 Mar 23. [Epub ahead of print] DOI: 10.1007/s00421-011-1918-z with permission from Springer.

Effect of Forest Environments on Sympathetic and Parasympathetic Nervous Activity

The sympathetic and parasympathetic nervous systems play a pivotal role in the regulation of blood pressure and heart rate: sympathetic nervous activity increases, whereas parasympathetic nervous activity reduces, blood pressure and heart rate [5]. Heart rate variability (HRV) as well as blood pressure and pulse rate are frequently employed to estimate changes in autonomic nervous activity. The R–R interval obtained from electrocardiograms is used to asses HRV. The power of the low-frequency (LF; 0.04–0.15 Hz) and high-frequency (HF; 0.15–0.4 Hz) components of the obtained heart rate power spectrum for each minute are generally calculated. HF power is considered to reflect parasympathetic nervous activity, and either LF/HF or LF/(LF+HF) is considered to be an index of sympathetic nervous activity [6]. Sympathetic nervous activity also can be determined by measuring the levels of urinary adrenaline and/or noradrenaline [7], and there are significant correlations between blood pressure and urinary adrenaline and noradrenaline levels [5]. It has been reported that forest environments reduce sympathetic nervous activity, increase parasympathetic nervous activity, and regulate the balance of autonomic nerves [8-10]. As a result, forest environments reduce blood pressure (Figure 3) and heart rate and have relaxing effects [8-11]. In addition, these effects indirectly influence the endocrine and immune systems via the psycho-neuro-endocrino-immune network, causing a reduction in urinary adrenaline and/or noradrenaline and an enhancement in natural killer (NK) activity in peripheral blood [12-16].

Effect of Forest Environments on Psychological Responses

Forest environments may influence psychological responses via the brain and nervous system. It has been reported that forest bathing significantly decreased the scores for anxiety, depression, anger, fatigue and confusion and significantly increased the score for vigor in the POMS test in both male and female subjects (Figure 4) [9, 12, 14, 16]. In addition, forest bathing is particularly effective against mental stress (mental fatigue) [16]. This suggests forest bathing to have a preventive effect on those in a depressed state. It is necessary to identify the preventive effect in patients with depression.

Effect of Forest Environments on the Endocrine System

Forest environments act on the endocrine system to reduce stress hormone levels such as urinary adrenaline, urinary noradrenaline (Figure 5) [13, 14, 16], salivary cortisol [9], and blood cortisol [16] levels and show relaxing effects [9, 12, 14, 16]. Because stress inhibits immune function [17], forest environments indirectly enhance immune function by reducing the levels of stress hormones [18, 19]. The usefulness of forest bathing for stress management should be clarified in the future. In addition, forest environments also significantly increase serum adiponectin and dehydroepiandrosterone sulfate (DHEA-S) levels [11]. Adiponectin is a serum protein hormone specifically produced by adipose tissue. Studies have shown that lower than normal blood adiponectin concentrations are associated with several metabolic disorders, including obesity, type 2 diabetes mellitus, cardiovascular disease, and metabolic syndrome [20]. Levels of DHEA and DHEA-S, the major secretory products of the adrenal gland, decline dramatically with age, concurrent with the onset of degenerative changes and chronic diseases associated with aging [21, 22]. Epidemiological evidence in humans suggests that DHEA-S has cardioprotective, antiobesity, and antidiabetic properties [21].

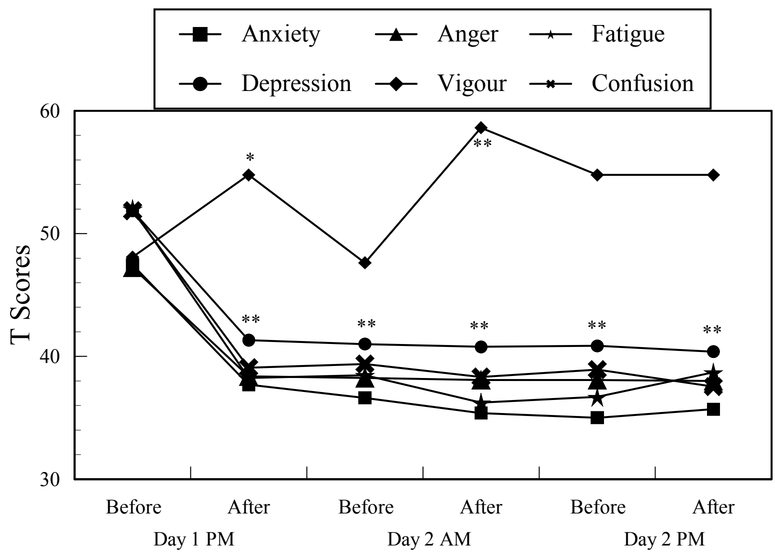

Figure 4. Effect of a three-day/two-night forest bathing trip on POMS scores in female subjects. Data are presented as the mean (n=13). *: p<0.05, **: p<0.01, significantly different from before the trip on Day 1 pm by paired t-test (anxiety, depression, anger, fatigue, and confusion). Cited from Li et al. J Biol Regul Homeost Agents. 2008;22:45-55 with permission from Biolife.

Effect of Forest Environments on the Immune System

The immune system including NK cells plays an important role in defense against bacteria, viruses and tumors. People with higher NK activity showed a lower incidence of cancers, whereas those with lower NK activity showed a higher incidence [23], indicating the importance of NK cell function to cancer prevention. In addition, patients with an advanced performance status had significantly fewer granulysin-positive NK cells than healthy controls; impaired expression of granulysin by NK cells correlates with progression of cancer, and determination of granulysin expression might prove informative for assessing the immunological condition of cancer patients, indicating the importance of granulysin to cancer progression [24].

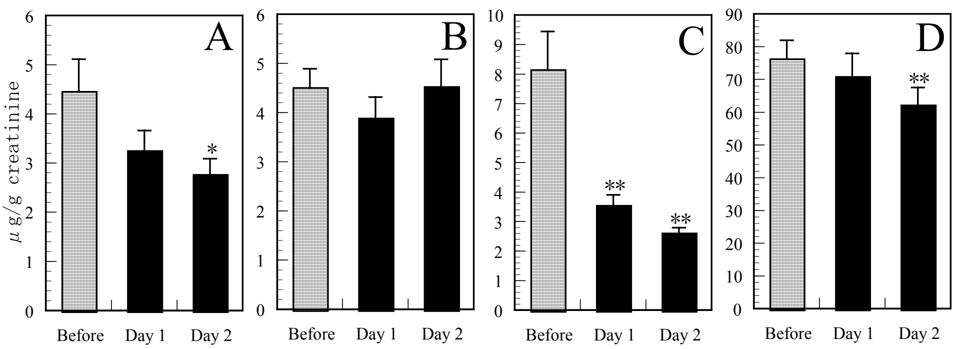

Figure 5. Effect of a forest bathing trip on adrenaline and noradrenaline concentrations in urine. A: Effect of a forest bathing trip on urinary adrenaline concentrations in males (n=12), B: Effect of a city trip on urinary adrenaline concentrations in males (n=11), C: Effect of a forest bathing trip on urinary adrenaline concentrations in females (n=13), D: Effect of a forest bathing trip on urinary noradrenaline concentrations in females (n=13). Data are presented as the mean+SE. *: $p<0.05$, **: $p<0.01$, significantly different from before the trip by paired t-test. Cited from Li et al. Int J Immunopathol Pharmacol. 2008;21:117-128 and Li et al. J Biol Regul Homeost Agents. 2008;22:45-55 with permission from Biolife.

Forest environments act directly on the immune system to promote human NK activity by increasing in the number of NK cells and intracellular levels of anti-cancer proteins such as perforin, granulysin and granzymes in both male and female subjects [12-14, 16]. On the other hand, stress/stress hormones inhibit immune function [17] and forest environments reduce the levels of stress hormones; therefore, forest environments also indirectly act on the immune system to increase NK activity via the autonomic nervous and endocrine systems mediated by stress hormones (Figure 6) [18, 19].

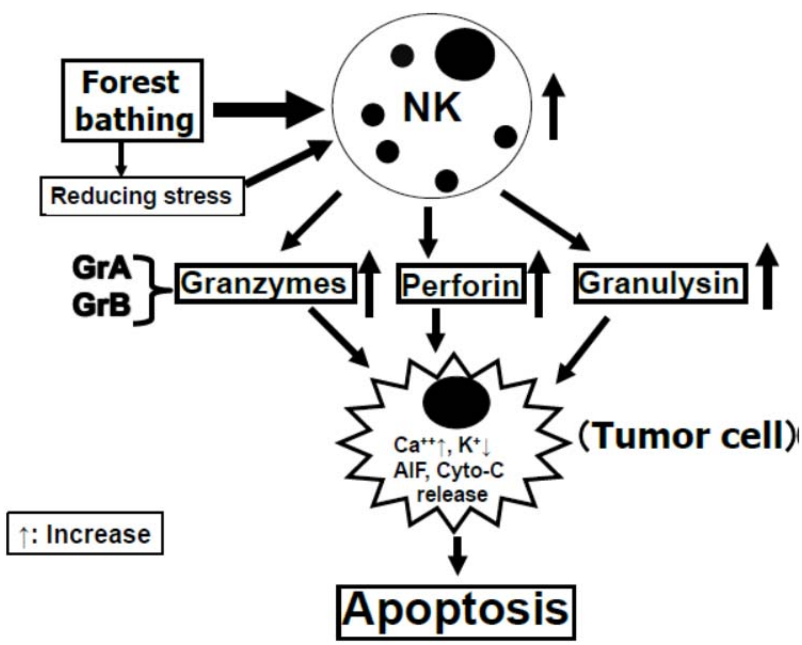

Figure 6. Mechanism of forest bathing-induced induction of NK activity. Cited from Li et al. Int J Immunopathol Pharmacol. 2011; 24 (S1): 39-44 with permission from Biolife.

Because NK cells can kill tumor cells by releasing anti-cancer proteins, and forest environments increase NK activity and the amount of anti-cancer proteins; the above findings also suggest forest bathing to have a preventive effect on cancer generation. In fact, people living in areas with lower forest coverage had significantly higher standardized mortality ratios (SMR) of cancer than people living in areas with higher forest coverage. There were significant inverse correlations between the percentage of forest coverage and the SMR of lung, breast, and uterine cancers in females, and the SMR of prostate, kidney, and colon cancers in males in all prefectures in Japan, even after the effects of smoking and socioeconomic status were factored in. These findings indicate that increased forest coverage may partially contribute to a decrease in mortality due to cancer in Japan [25].

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Section 4. Effects of Factors in the Forest Environment on Human Health

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Chapter 13

Effect of Phytoncides from Forest Environments on Immune Function

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Abstract

We previously reported that the forest environment enhanced human natural killer (NK) activity, the number of NK cells, and intracellular levels of anti-cancer proteins in lymphocytes, and that the increased NK activity lasted for more than 7 days after trips to forests in both male and female subjects. To explore the factors in the forest environment that activated human NK cells, we investigated the effect of essential oils from trees on human immune function both in vitro and in vivo. In the in vitro study, we investigated the effect of 8 kinds of phytoncides (wood essential oil) on NK activity and the expression of perforin, granzyme A (GrA) and granulysin (GRN) in human NK cells. We found that phytoncides significantly increased NK activity in a dose-dependent manner and significantly increased the expression of perforin, GrA and GRN. The phytoncides also partially restored NK activity and perforin, GrA and GRN levels reduced by DDVP. We found that pretreatment with phytoncides partially prevented the DDVP-induced inhibition of NK activity. These findings suggest that phytoncides can increase human NK activity. In the in vivo study, twelve healthy male subjects, aged 37−60 years, were put up in urban hotel for 3 nights. Aromatic volatile substances (phytoncides) were produced by vaporizing *Chamaecyparis obtusa* stem oil with a humidifier in the hotel room during the night. Blood was sampled on the last day and urine was sampled every day during the stay. Similar control measurements were made before the stay on a normal working day. The concentrations of phytoncides in hotel room air were measured. Phytoncide exposure significantly increased NK activity and the numbers of NK, perforin, GRN, and GrA/B-expressing cells, and significantly decreased the

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concentrations of adrenaline and noradrenaline in urine. These findings indicate that phytoncide exposure and decreased stress hormone levels partially contribute to increased NK activity.

Keywords: anti-cancer proteins, granulysin, granzyme, NK activity, perforin, phytoncides

Introduction

We previously found that the forest environment enhanced human natural killer (NK) activity, the number of NK and NKT cells, and intracellular levels of anti-cancer proteins in lymphocytes, and that the increased NK activity lasted for more than 7 days after the trips to forests in both male and female subjects [1-7]. However, it is not clear what factors in the forest environment activated the NK cells. We speculate that aromatic volatile substances including monoterpenes and sesquiterpenes, called phytoncides, consisting of volatile organic compounds derived from trees, such as α-pinene and limonene [8], play an important role. Thus, we investigated the effects of phytoncides on human immune function both *in vitro* [8] and *in vivo* [9].

Effect of Phytoncides (Essential Oils) from Trees on Human Immune Function *In Vitro*

To investigate the mechanism of the effect of forest trips on human immune function, first of all, the effects of phytoncides on human NK activity and intracellular levels of perforin, granzyme A (GrA), and granulysin (GRN) in NK cells were studied *in vitro*. It has been reported that NK cells kill tumor or virus-infected cells by the release of perforin, granzymes, and GRN via the granule exocytosis pathway [10-15]. In this study, NK-92CI and NK-92MI cells, which are interleukin-2 independent human NK cell lines derived from NK-92 cells, were used. We confirmed that both NK-92CI and NK-92MI cells express the surface marker CD56, and intracellular perforin, GrA/B/3/K and GRN by flow cytometry, and were highly cytotoxic to K562 cells in the chromium release assay [8,12-13]. NK cells were incubated in the presence of phytoncides such as α-pinene, 1,8-cineole, *d*-limonene, and essential oils extracted from trees including Japanese cedar (*Cryptomeria japonica*, Sugi in Japanese) and *Chamaecyparis obtuse* (Hinoki in Japanese) for 48-144 hr, then NK activity and the intracellular levels of perforin, GrA, and GRN were measured [8]. It was found that phytoncides significantly increased the cytolytic activity of NK-92CI and NK-92MI cells in a dose-dependent manner (Figure 1) and significantly increased the intracellular levels of perforin, GrA, and GRN (Figure 2) in NK-92MI cells. Phytoncides also partially, but significantly, restored the decreased human NK activity and the decreased perforin, GrA, and GRN levels in NK-92MI cells treated with dichlovos, an organophosphorus pesticide. Pretreatment with phytoncides partially prevented the dichlovos-induced inhibition of NK activity.

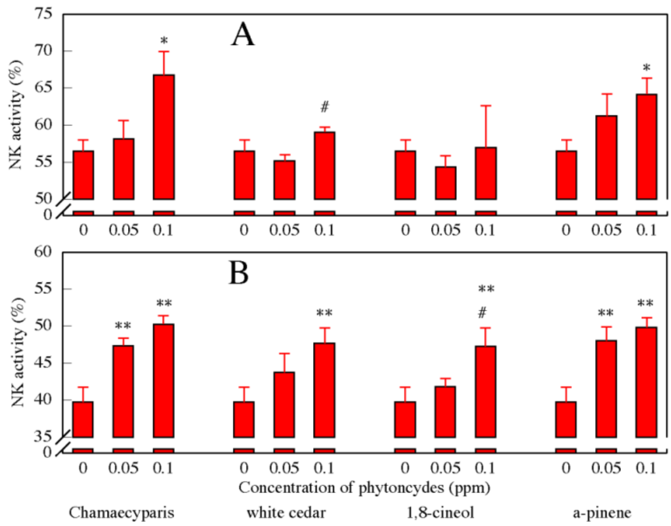

Figure 1. Effect of phytoncides on NK activity of NK-92MI cells exposed for 120h (A) and 144h (B). One-way ANOVAs indicated that 4 of the phytoncides significantly affected NK activity for 120h (A) and 144h (B) (all p<0.05) but 1,8-cineole at 120h did not. *: p<0.05, **: p<0.01, significantly different from 0 ppm, #: p<0.05 significantly different from 0.05 ppm by Tukey's method. The activity values for an E/T ratio of 0.5/1 are presented, and similar results were obtained with other E/T ratios. Cited from Li et al. Immunopharmacol Immunotoxicol. 2006;28:319-33 with permission from Informa Healthcare.

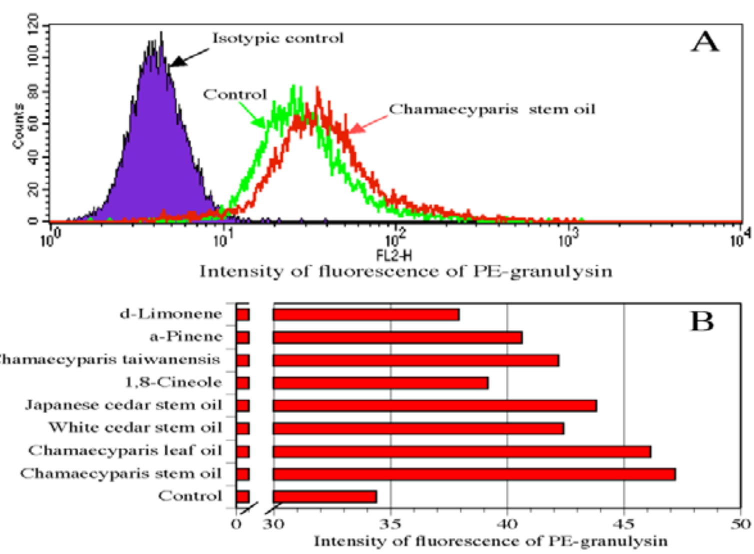

Figure 2. Effect of phytoncides on the expression of granulysin in NK-92MI exposed for 120 h *in vitro.* A: the solid histogram shows the control stained with PE-anti-rabbit IgG (isotype controls), the open histograms show the results obtained with PE-anti-human granulysin in the cells not exposed to phytoncides (control), and the cells treated with Japanese cypress (*Chamaecyparis)* stem oil at 0.1ppm, respectively; B: the intensity of the fluorescence of PE-anti-human granulysin in NK-92MI among different phytoncides. All experiments were repeated at least 3 times with very similar results. Cited from Li et al. Immunopharmacol Immunotoxicol. 2006;28:319-33 with permission from Informa Healthcare.

Taken together, these results indicate that phytoncides significantly enhanced human NK activity and this effect is at least partially mediated by the production of perforin, GrA, and GRN [8]. da Silva et al. [16] found that a volatile oil from Zanthoxylum rhoifolium Lam leaves and certain terpenes (α-humulene, ß-caryophyllene, α-pinene, and ß-pinene) exhibited anti-tumor effects and significant immunomodulatory activity *in vivo* and *in vitro*. Moreover, Grassmann et al. [17] found that an essential oil from *Pinus mugo* had antioxidative properties.

These findings strongly suggest that phytoncides have beneficial effects on human immune function. Thus, we further investigated the effect of tree-derived phytoncides on immune function in male subjects *in vivo*.

Effect of Phytoncides (Essential Oils) from Trees on Human Immune Function *In Vivo*

In this experiment [9], twelve healthy male subjects, aged 37−60 years (51.8± 7.3), were selected from a medical school in Tokyo, Japan. None of the subjects had any signs or symptoms of infectious disease, used drugs that might affect an immunological analysis, or were taking any medications at the time of the study. Written informed consent was obtained from all subjects after a full explanation of the study procedures. The Ethics Committee of the Nippon Medical School approved this study (approval No. 16-1). The subjects stayed in an urban hotel in Tokyo for three consecutive nights. On the first day, urine was sampled at 0700 at their homes, blood was sampled at 0830 at a hospital, and several questionnaires including the Profile of Mood States (POMS), were completed as a control before the stay. The subjects then worked as usual. From 1900, all subjects stayed at the same hotel in the same type of room. During the night, aromatic volatile substances (phytoncides) were produced by vaporizing *Chamaecyparis obtusa* stem oil with a humidifier in the hotel room. All subjects went to bed at 2300. On the second day, the subjects got up at 0700, took a urine sample, completed the questionnaires and ate breakfast, and then went to their workplace and worked as usual. They stayed at the hotel for three consecutive nights. On the last day, the subjects got up at 0700, took urine samples, completed the questionnaires and underwent blood sampling at 0830 at the hospital, finished the experiment and returned to their workplace. Daily physical activity of the subjects was monitored with a pedometer [1-5], a week, and the average for all subjects was about 10000 steps/day. We set the walking steps during the experiment based on this result. The duration of sleep was measured with a piezo-electric accelerometer, Actiwatch (R) (Mini Mitter Co. Inc., Sunriver), worn on the wrist of the non-dominant arm [1-5]. Since it has been reported that human NK activity shows circadian rhythms [18], all samples were obtained at 0830. White blood cell (WBC) counts, NK activity, proportions of NK and T cells, and GRN, perforin, and granzymes A/B-expressing cells in peripheral blood lymphocytes (PBLs) were measured. Adrenaline and noradrenaline concentrations in urine were also determined as reported previously [1-3]. The POMS test in Japanese was used to examine mood changes of each subject before and after the stays [1, 3].

Phytoncides, such as α-pinene, β-pinene, β-cadinene, limonene, α-muurolene, and γ -muurolene, were detected in the hotel room air during the experiment, and α-pinene was the main phytoncides (approximately 50%). There was no significant difference at the concentrations of α-pinene and the total concentration of phytoncides in air among the different days and the different rooms. The average temperature and humidity in the hotel rooms were 24.2±1.1°C and 55.9±5.5%, respectively.

Phytoncide exposure significantly increased human NK activity (Figure 3A) and the percentage of CD16+ NK cells (Figure 3B). The phytoncides did not affect lymphocyte or WBC counts. Komori et al. [19] reported that a citrus fragrance found in forests affected the human endocrine and immune systems as analyzed by the measurement of urinary cortisol and dopamine levels, NK activity, and CD4/8 ratios. Sun and Peng [20] also found that triterpenoid fractions from the rhizomes of Astilbe chinensis provided significant protection against cyclophosphamide-induced inhibition of murine NK activity. β-Carotene, a terpenoid, is a red-orange pigment abundant in plants and fruits. Santos et al [21] found that β-carotene enhanced NK activity in elderly men living in Boston, USA in a randomized, placebo-controlled, double-blind study, suggesting that terpenes can activate NK cells.

These findings suggest that phytoncides including terpenes contributed to the enhanced NK activity during the stay at the hotel. NK cells kill tumor or virus-infected cells by releasing perforin, granzymes, and GRN via the granule exocytosis pathway [10-15].

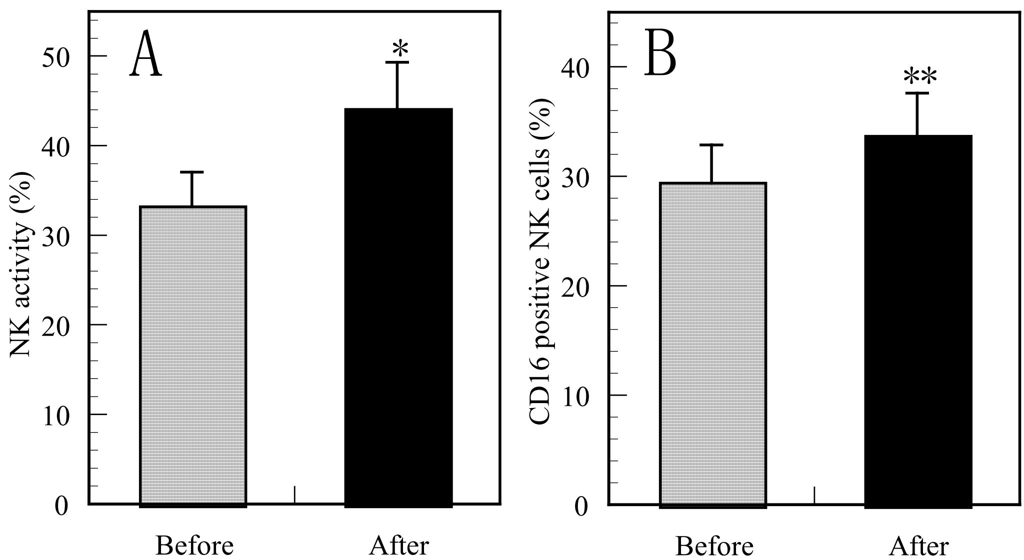

Figure 3. Effect of phytoncides on human NK activity (A) and the percentage of $CD16^+$ NK cells (B). Data are presented as the mean+SE (n=12). *: p<0.05, **: p<0.01 significantly different from before the exposure by paired t-test. The activity values for an E/T ratio of 20/1 are shown, and similar results were also obtained with E/T ratios of 40/1 and 10/1. The columns labeled “Before” indicate NK activity and $CD16^+$ cells determined before the exposure; the columns labeled “After” indicate NK activity and $CD16^+$ cells determined after the exposure. Cited from Li et al. Int J Immunopathol Pharmacol. 2009;22:951-9 with permission from Biolife.

To explore the mechanism by which NK activity is enhanced by phytoncides, we investigated the effect of phytoncide exposure on the intracellular levels of perforin, GRN, and GrA/B in PBLs. Phytoncides significantly increased the percentages of GrA/B (Figures 4A, 4B)-, and perforin (Figure 4C)-expressing cells. Although they also increased the percentage of GRN-expressing cells (Figure 4D), the effect was not significant (p=0.081) [8].

These cytolytic molecules contribute to NK and anti-tumor activity [14-15]. Levels of free adrenaline and noradrenaline in urine provide a reliable measure of the concentrations of adrenaline and noradrenaline in the bloodstream and thus a measure of sympathoadrenal medulla activity [22]. The concentrations of adrenaline and noradrenaline in urine have been used to evaluate work-related stress in nurses [23], lorry drivers [24], and long-distance coach drivers [25], and psychosocial stress [26]. Although phytoncides decreased the concentrations of adrenaline, the effect was not significant (p=0.345). However, when the subjects were divided into two groups: an increased group (2 subjects) and a decreased group (10 subjects), it was found that there was a significant decrease in the decreased group (10 subjects) (Figure 5.b), indicating individual differences in the response to phytoncides.

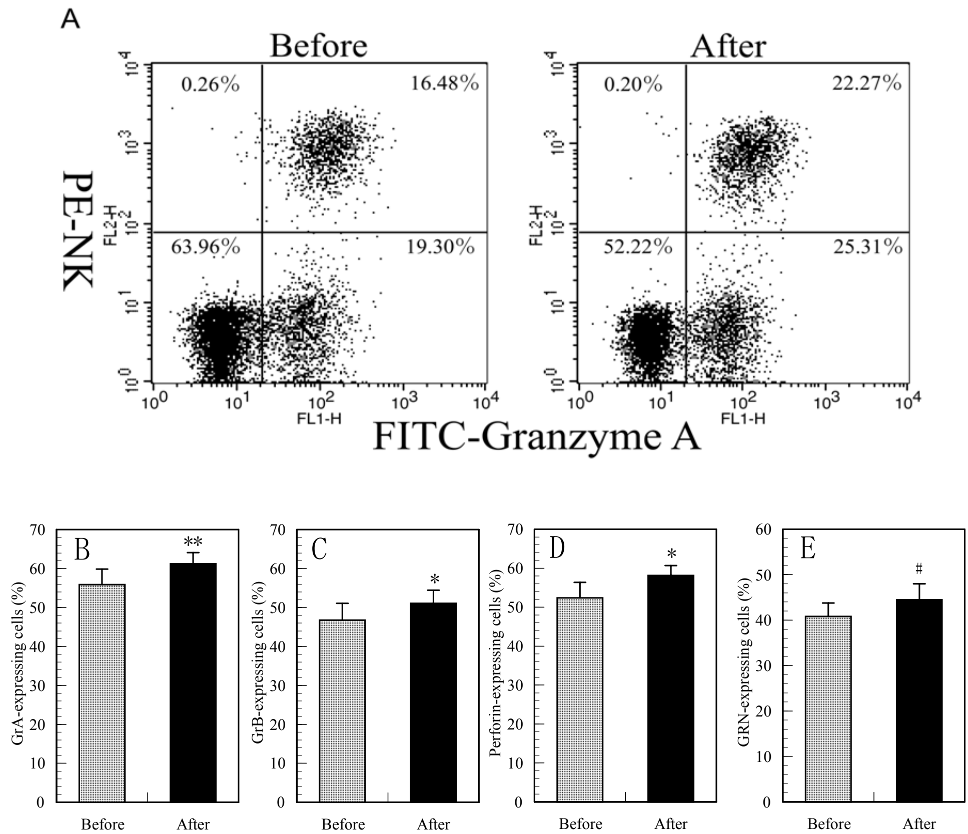

Figure 4. Effect of phytoncides on GrA/B- (A-C), perforin (D)-, and GRN (E)- expressing cells in PBLs. A: Dot plots of FITC-GrA/PE-CD16-positive cells in PBLs of a subject before (left) and after (right) phytoncide exposure. The horizontal axis shows the intensity of fluorescence of FITC-GrA, while the vertical axis shows the intensity of fluorescence of PE-CD16 (NK cells). Percentages in quadrants 2 and 3 show GrA^+/ $CD16^+$ and GrA^+/ $CD16^-$ cells, respectively. Data are presented as the mean+SE (n=12). *: p<0.05, **: p<0.01, significantly different from before the exposure by paired t-test. #: p=0.081 different from before the exposure by paired t-test. The columns labeled "Before" indicate GrA/B, perforin and GRN-expressing cells determined before the exposure; the columns labeled "After" indicate GrA/B, perforin and GRN-expressing cells determined after the exposure. Cited from Li et al. Int J Immunopathol Pharmacol. 2009;22:951-9 with permission from Biolife.

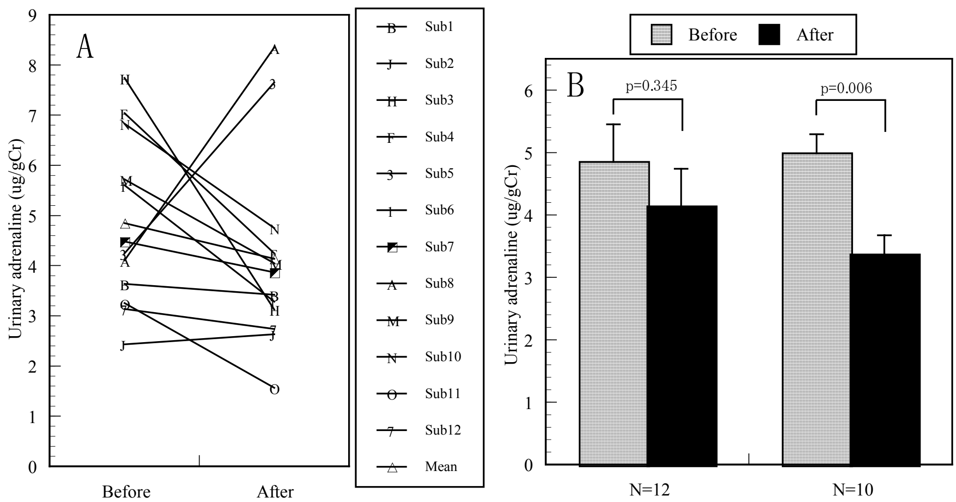

Figure 5. Effect of phytoncides on urinary adrenaline concentrations. A: urinary adrenaline levels in 12 subjects, B: Data are presented as the mean+SE (n=12 for all subjects and n=10 for subjects with decreased urinary adrenaline levels). Statistical significance was analyzed with the paired t-test. The columns labeled “Before” indicate urinary adrenaline levels determined before the exposure; the columns labeled “After” indicate urinary adrenaline levels determined after the exposure. Cited from Li et al. Int J Immunopathol Pharmacol. 2009;22:951-9 with permission from Biolife.

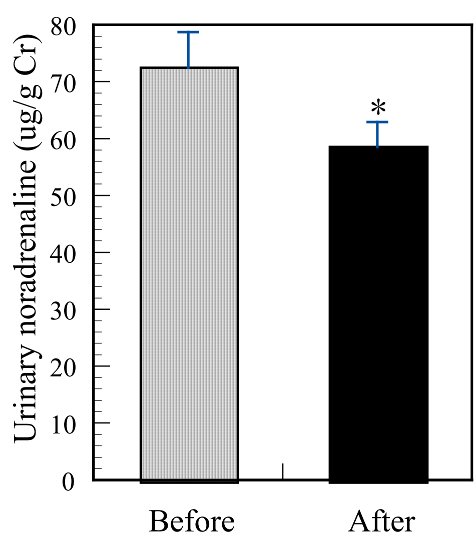

Figure 6. Effect of phytoncides on urinary noradrenaline concentrations. Data are presented as the mean+SE (n=12). *: $p<0.05$ significantly different from before the exposure by paired t-test. The column labeled “Before” indicates urinary noradrenaline levels determined before the exposure; the column labeled “After” indicates urinary noradrenaline levels determined after the exposure. Cited from Li et al. Int J Immunopathol Pharmacol. 2009;22:951-9 with permission from Biolife.

On the other hand, phytoncide exposure significantly decreased the concentrations of noradrenaline in urine (Figure 6), suggesting that the subjects had lower stress levels during the hotel stay [8]. Haze et al. found that the inhalation of rose oil or patchouli oil caused a

40% decrease in relative sympathetic activity and that the inhalation of rose oil caused a 30% decrease in the adrenaline concentration in plasma, indicating that the fragrance of essential oils may modulate sympathetic activity in normal adults [27], which supports our findings. In addition, exposure to phytoncides significantly decreased the scores for fatigue and confusion in the POMS test [9], suggesting that the subjects were physiologically relaxed during the hotel stay. Schiffman et al [28] also found that the use of pleasant odors improved the mood of males at midlife in the POMS test. It has been reported that adrenaline inhibits human NK activity [29].

Addition of noradrenaline to intrathecal morphine augments the postoperative suppression of natural killer cell activity [30], suggesting that noradrenaline also inhibits human NK activity. We found previously that physical and/or psychological stress decreased NK activity, NK receptor levels, and the mRNA transcription of granzymes and perforin in mice [31]. The increase in NK activity during phytoncide exposure may be related to an attenuated stress hormone response (adrenaline, noradrenaline).

Phytoncide exposure significantly decreased T cells in male subjects. We previously found that the forest environment also significantly decreased T cells in both male and female subjects [1-3]. It has been reported that mental stress increased T cells in PBLs [32-33]. We have also found that people with an unhealthy lifestyle showed a higher percentage of T cells than people with a healthy lifestyle [34]; therefore, the proportion of T cells in PBLs may reflect stress status [3]. Many factors, including circadian variation [18], physical exercise [34], and alcohol consumption [34-35], can affect human NK activity. In order to control the effect of circadian rhythm on NK activity, we sampled blood at 0830 on all days. To control for the effect of physical exercise on NK activity, we limited the walking during the experiment to average workday distances. To control the effect of alcohol on NK activity, the subjects did not consume alcohol for 2 days before providing the blood sample during the study period.

The Swedish occupational exposure value for a mixture of monoterpenes (phytoncides) and a single monoterpene is 150 mg/m^3 (approximately 27 ppm) and the Finnish occupational exposure limit is 570 mg/m^3 (approximately 102 ppm) [36-37]. The concentrations of α-pinene (less than 1 ppm) and total concentration of phytoncides (less than 2 ppm) in the hotel room in the present study were far less than the occupational exposure values, suggesting that the phytoncides would not have any adverse effects on health, including immune function, and that exposure at the present concentrations should be safe. In fact, all subjects answered that they were comfortable during their stay. We previously found that staying in an urban hotel room in the absence of phytoncides for 2 nights did not affect NK activity, numbers of NK cells and perforin-, GRN-, and GrA/B-expressing lymphocytes, or urinary adrenaline and noradrenaline levels [2], suggesting that the increased NK activity in the present study was not due to the stay at the hotel, but to phytoncide exposure.

Although we observed beneficial effects from short-term exposure to phytoncides, it is necessary to conduct epidemiological studies or perspective studies in a population exposed to phytoncides in daily life to confirm the effect on human immune function.

In summary, phytoncides from trees can increase NK activity, the number of NK cells, and the expression of intracellular perforin, GrA/B, and GRN in male subjects. Phytoncides in forest air may partially contribute to the increased NK activity in subjects visiting forests [1-7].

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Chapter 14

Physiological Effects of Visual, Olfactory, Auditory, and Tactile Factors of Forest Environments

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Abstract

The forest environment affects humans via the five senses, providing stimulation of various kinds such as scenery, the smell of wood, the sound of streams or the rustle of leaves, and the feel of the surface of trees and leaves. Many laboratory experiments have been conducted to elucidate the physiological effects of sensory inputs in forest environments.

In this chapter, we will initially examine some non-invasive physiological methods that can be applied in a laboratory study to assess physiological changes. Recent progress in technology has enabled the precise non-invasive investigation of physiological responses.

Various measurement methods will be shown for each physiological function. We will then provide an overview of studies on the effects of certain elements of the forest environment within a laboratory setting. Studies have revealed that the components of a forest environment, even if as components of stimulation, may have a positive effect on human physiology.

Keywords: Near-infrared spectroscopy, Blood pressure, Pulse rate, Heart rate variability, Salivary cortisol, Therapeutic effects of forests

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Introduction

The forest environment affects humans via the five senses, providing stimulation of various kinds such as scenery (vision), the smell of wood (olfaction), the sound of streams or the rustle of leaves (audition), and the feel of the surface of trees and leaves (tactile sensation). Sensory information inputs via the five senses are processed in the corresponding sensory areas of the brain, and are further transmitted through interaction among the various sensory inputs. These signals subsequently reach the areas of the brain that control emotions and physiological functions, and thereby cause physiological changes.

To elucidate the physiological effects of each sensory input, various laboratory experiments have been conducted. There are two main reasons for conducting laboratory experiments in the field of forest medicine. One is to obtain backup data for field studies or to undertake a detailed analysis of the results of these studies. This consequently makes it a requirement to introduce measurements with high time and spatial resolution in the studies. The second reason is to assess the effects of elements of nature when subjects are brought into an artificial environment (e.g., scenery shown in the form of a poster or smell introduced in the form of aroma therapy).

In this chapter, we will first look at some non-invasive physiological methods that can be applied in a laboratory study to assess the physiological changes in respondents when exposed to stimulation. The recent progress of technology has enabled high-precision measurements while achieving portability and affordability. Some of the devices were developed for clinical use, and are therefore user-friendly. We will then provide an overview of the studies designed to elucidate the effects of certain elements of the forest environment within a laboratory setting by examining reports of previous studies.

Physiological Measurements

Measurement of Central Nervous Activity

There are several indices of central nervous activity, some of which measure the electrical activity produced by nerves firing in the brain, and some of which measure oxygenation that accompany brain activation. The best known may be electroencephalography (EEG), the measurement of changes in electric potential that occur along with brain activity using sensors attached on the scalp. There is an abundance of research findings on EEG as it has been used since the earliest days of brain research. It should, however, be noted that EEG is sometimes inappropriate to be employed in studies aimed at human comfort because adhesive pastes used to attach electrodes possibly give discomfort during EEG. Recently, a method using light called near-infrared spectroscopy (NIRS) [1, 2] has become more widely used.

NIRS is able to measure concentration changes in oxygenated and deoxygenated hemoglobin associated with brain activity with a 1-s time resolution, utilizing the differences in infrared absorption between the two hemoglobins. The sensors can be easily attached with double-sided tape, and thus, less stress is caused by the measurement itself, compared to other methods such as electroencephalography. NIRS equipment is portable and sufficiently robust to be suitable for conducting measurements even in the field. Adequate light shielding should, nevertheless, be provided since the measurements are based on the principle of near-infrared light transmission.

The most recent interesting feature of this method is the possibility of measuring absolute hemoglobin concentration by using time-resolved spectroscopy (TRS) [3, 4]. Previously, NIRS could only measure relative changes in hemoglobin concentration from a certain baseline. However, the development of techniques for measuring the actual optical path length and solving a light diffusion equation using picosecond pulses has made it possible to obtain an absolute value for hemoglobin concentration based on the assumption of the existence of homogenous optical properties beneath each optode. The changes in absolute hemoglobin concentrations induced by walking or viewing scenery in forest and in urban environments have been previously reported [5]. To date, this is the only example of applying TRS in the field.

Measurement of Autonomic Nervous Activity

Signals from the central nervous system are transmitted via the autonomic nervous system to control various organs in the body. Indices of the autonomic nervous activity are known to reflect one's emotional state as well as involuntary responses to external stressors. Measurement of most of the autonomic indices is relatively handy and is widespread among researchers.

Heart rate i.e., the number of heartbeats per minute is one of the most basic indices of the autonomic nervous activity, and is generally lowered in a relaxed physiological state. Another principal vital sign is blood pressure. Systolic and diastolic blood pressure, which are caused by contractions and dilatations of the heart, respectively, are usually used as indices of the autonomic nervous activity. Blood pressure is lowered in a relaxed physiological state as in the case of heart rate. In laboratory studies, a noninvasive method to measure continuous blood pressure with a finger cuff called the Finapres method is widely practiced.

Heart rate variability (HRV) [6] is also frequently employed. In our experiments, an ambulatory electrocardiogram monitor (AC301A; GMS Corporation) was attached to the subjects to store the data of R-R interval for assessing HRV before, during, and after the subjects walked around or viewed the scenery in the forest area. Subsequently, R-R interval data were analyzed by using the maximum entropy method [7] (Memcalc, GMS). Generally, the power of the low-frequency (LF; 0.04–0.15 Hz) and high-frequency (HF; 0.15–0.4 Hz) components of the obtained heart rate power spectrum for each minute are calculated. HF power is thought to reflect parasympathetic nervous activity, and either LF/HF or LF/(LF + HF) is thought to be an index of sympathetic nervous activity [6]. The results indicated more enhanced parasympathetic and lower sympathetic nervous activity in subjects in a forest environment than those in an urban environment [8]. HRV analysis is thus a useful method for detecting the sympathetic and parasympathetic nervous activity separately on a minute-by-minute basis.

The most recent technique to assess autonomic nervous activity involves the measurement of salivary amylase. Secretion of salivary amylase is controlled by the sympathetic-adrenal-medullary system. Recently, more rapid secretion of salivary amylase under sympathetic nerve regulation has attracted attention as a parameter that reflects mental stress [9]. Equipment that evaluates amylase activity on-site in one or two minutes has recently been developed [10]; this equipment has now been tested in various studies. Since sampling of saliva causes considerably less stress in subjects than does sampling of blood or urine, there are high expectations for this method as a new means of evaluating mental stress expressed via sympathetic nervous activity.

Biomarkers Reflecting Stress Response

Stress levels may be assessed by determining the amounts of endocrine or immune substances secreted in response to stressors. As an index of endocrine activity, a typical stress hormone, cortisol, whose secretion is enhanced under stress, is very widely used. Immunoglobulin A (IgA), an antibody found in blood and other body fluids is often considered an index of immune system activity. Earlier, concentrations of these substances could be determined only from blood or urine samples; however, determining low concentrations of these samples and their measurements using saliva samples has been enabled due to recent technological developments.

In field studies, we have clarified that cortisol concentration is significantly lower in subjects exposed to a forest environment than in those exposed to an urban environment [8]. However, the results for IgA concentration were not consistent. IgA concentration is known to decrease under severe chronic stress [11], whereas it has been reported to increase in response to acute stress [12]. Interestingly, however, it has also been demonstrated that IgA levels in those who are engaged in stressful jobs are significantly higher than the levels in those who are not engaged in comparable activity [13]. It is thus thought that the use of IgA concentration as a stress marker should be re-evaluated by investigating the relationship between its change and the types and continuity of emotional stress.

It is known that there are large individual differences in the baseline values of salivary cortisol and salivary IgA concentrations. It was recently found that there was a significant negative correlation between the baseline value and the amount of change in both salivary cortisol and IgA levels when walking and viewing scenery in both forest and city environments [14]. This finding will contribute to the interpretation of the individual differences in cortisol and IgA responses.

Laboratory Studies

Physiological Responses to Visual Stimulation of Forest Environments

Ulrich et al. conducted physiological and psychological measurements on 120 participants and found that natural sceneries have a positive influence on stress recovery [15]. In this study, each participant first viewed a 10-minute video on work accidents with several serious injuries (stressor), and then a video of one of six outdoor sceneries (two natural and four urban settings) for 10 minutes (recovery). During the stressor session, skin conductance and muscle tension significantly increased and pulse transit time significantly decreased. These were interpreted as anticipated responses to the stressor. In the recovery session, the time-course recovery curves of these indices varied widely depending on the kind of environment viewed. Recovery from stress was faster and more complete in the individuals who were exposed to the natural settings than in those exposed to the urban environments. The authors concluded that these findings were in agreement with the psycho-evolutionary theory in which restorative effects of nature involve a shift towards to a more positive emotional state.

Lee and Watanuki investigated the differences between the cardiovascular responses of Type A and Type B subjects to visual stimulation of displeasure-evoking images and nature-video clips [16]. Significant differences were observed in the heart rate and cardiac output of Type A and Type B persons when they viewed displeasure-evoking images, i.e., Type A individuals showed a smaller decrease in heart rate and a significant increase in cardiac output. However, in the "post-stress session," where the subjects watched the nature-video clips, no significant effects of the Type A/B tendency or interactions between Type A/B tendency and the kind of visual stimulus were observed for any physiological recoveries. The authors assumed that nature-video clips might be effective to normalize the stress-induced cardiovascular responses in Type A individuals as there were no differences between Type A and Type B subjects with respect to the physiological recovery responses.

Tsunetsugu et al. investigated the visual effects of wooden room interiors by evaluating physiological responses in mock living rooms [17, 18]. In a room with a 30% wood ratio (i.e., the ratio of the area covered with wooden material to the whole area of the ceiling, walls, and floor), which is the standard type of living room commercially available in Japan [19], the pulse rate and diastolic blood pressure significantly decreased; this indicated the relaxing effect of this type of interior. A 45% wood ratio room tended to be evaluated as the most comfortable; further, when this wood ratio was utilized, the highest scores in the "vigorous" feeling in the mood test were generated. Pulse rates significantly increased in the 45% wood ratio room, which was considered to agree with the results of mood evaluation. A 90% wood ratio room initially caused a significant decrease in both systolic and diastolic blood pressure; however, this wood ratio subsequently led to a rapid decrease in prefrontal activity and an increase in pulse rate. In the subjective evaluation, all the wooden interiors were rated as "comfortable"; however, physiological measurements revealed that an excessive amount of wood caused an awakened response. It was hypothesized that there would be an appropriate wood quantity in the presence of which people experienced physiological relaxation.

Olfactory Stimulation

Phytoncides [derived from "phyto" (referring to plant) and "cide" (meaning "to kill")] are defined as volatile or nonvolatile substances produced by all kinds of plants that have an influence on other organisms [20]. Phytoncide is a general name for a range of substances and the chemicals tend to differ from forest to forest. The atmospheric concentrations of phytoncides in forests are very low and vary depending on many factors such season, climate, and forest composition. Thus, it would be reasonable to assume that the effects of forest environments are complex and are comprised of all the elements associated with the senses, including phytoncides. Phytoncides are olfaction-related elements of the forest environment. Smells are associated with instinct, emotion, and preference, and have a greater influence on physiological change as compared to the stimuli for other senses [21]. Trees have scents that are species-specific. Miyazaki et al. revealed that the smell of Japanese cedar chips, whose odor is familiar to the Japanese, significantly decreased systolic blood pressure, particularly at 40 to 60 s following the commencement of inhalation (Figure 1) [22]. Furthermore, the prefrontal area also exhibited a rapid decrease in activity, which became significant following 70–90 s of inhalation (Figure 2). The subjects evaluated the smell as “preferable.” The smell of Japanese cedar wood improved subjective comfort and caused a relaxed physiological state.

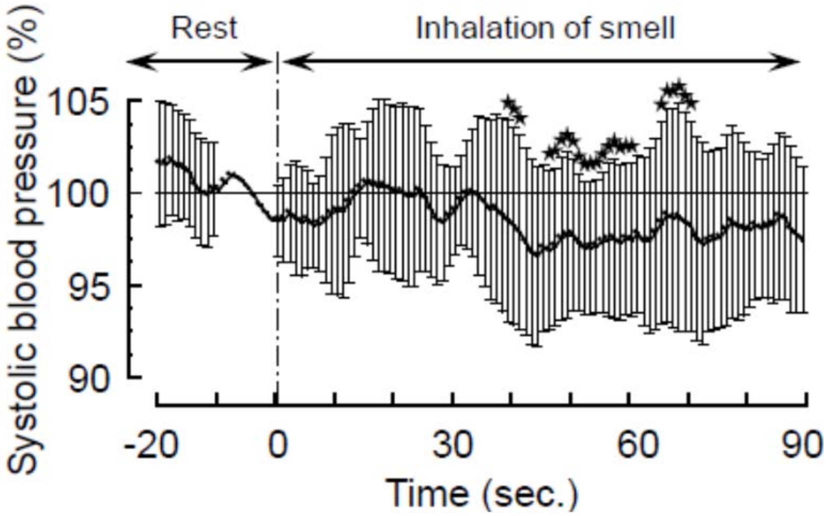

Figure 1. Time-course changes in systolic blood pressure in response to inhalation of the smell of Japanese cedar (shown as relative changes to the average values over 10 s before stimulation). Mean ± SD, N=14, * : p<0.05, ** : p<0.01 (compared to the average values over 10 s before stimulation).

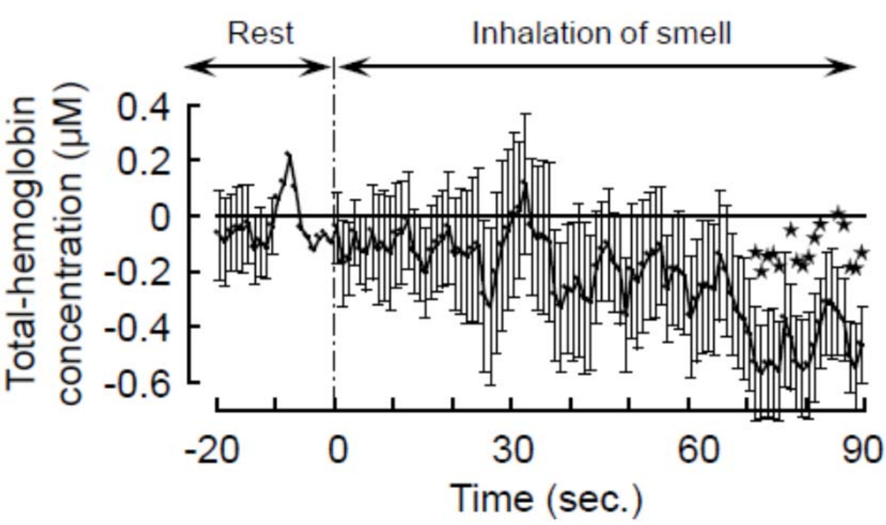

Figure 2. Time-course changes in prefrontal total hemoglobin concentration in response to inhalation of the smell of Japanese cedar (shown as deviations from the average values over 10 s before stimulation). Mean ± SD, N=14,* : p<0.05, ** : p<0.01 (compared to the average values over 10 s before stimulation).

There are large individual differences in odor preferences. In this experiment, although Japanese cedar was evaluated as “preferable” on average, there were some subjects who disliked the smell. However, contrary to expectation, there was no rise in the blood pressure of those subjects with an aversion to the smell. The authors assumed that human physiology has adapted to the natural environment, and that the smell of natural matter does not lead to stress despite the fact that it is perceived as being unpleasant.

Hiba (Thujopsis dolabrata) is also a commonly used species in Japan that possesses a characteristic smell. Hiruma et al. investigated the effects of the odor of hiba on contingent negative variation (CNV) and mismatch negativity (MNN) [23]. The amplitude of the CNV components was significantly larger under the odor condition than in the no-odor condition while the amplitude of the MNN showed no difference whether or not the odor existed. The authors interpreted the results to be attributable to the nervous system being roused by the odor of hiba without affecting the autonomic information process.

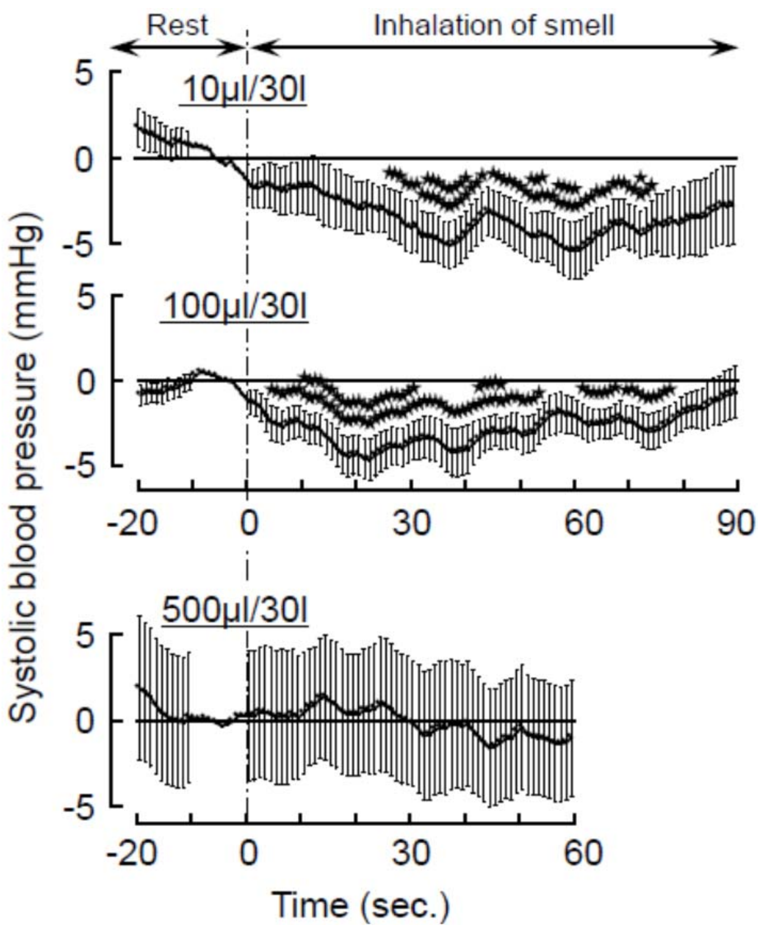

Figure 3. Time-course changes in systolic blood pressure in response to inhalation of α-pinene at different concentrations (shown as deviations from the average values over 10 s before stimulation). Mean ± SD, N=15-17, * : $p<0.05$, ** : $p<0.01$ (compared to the average values over 10 s before stimulation).

One of the major components of wood scent is α-pinene: it is generally detected in the air of coniferous forests. Tsunetsugu et al. investigated the effects of the concentration of α-pinene on human physiological responses [24]. The 10 μL/30 L (10μL of α-pinene in 30 L of air, hereafter the same) and 100 μL/30 L concentrations, which were rated as "slight odor" and experienced to be "slightly comfortable" in the subjective evaluation, caused decreased systolic blood pressure. However, the 500 μL/30 L concentration, which was rated as a "strong odor" and "slightly uncomfortable," did not cause a decrease in systolic blood pressure but did increase pulse rate (Figure 3). The 500 μL/30 L concentration that caused the slightly uncomfortable experience was considered to induce dominant sympathetic nervous activity. The increase in prefrontal activity was enhanced concomitant with the increase in the concentration of α-pinene (Figure 4). These results indicated that a weak smell of α-pinene induced a relaxed physiological state, whereas a relatively strong smell of α-pinene induced a stress state.

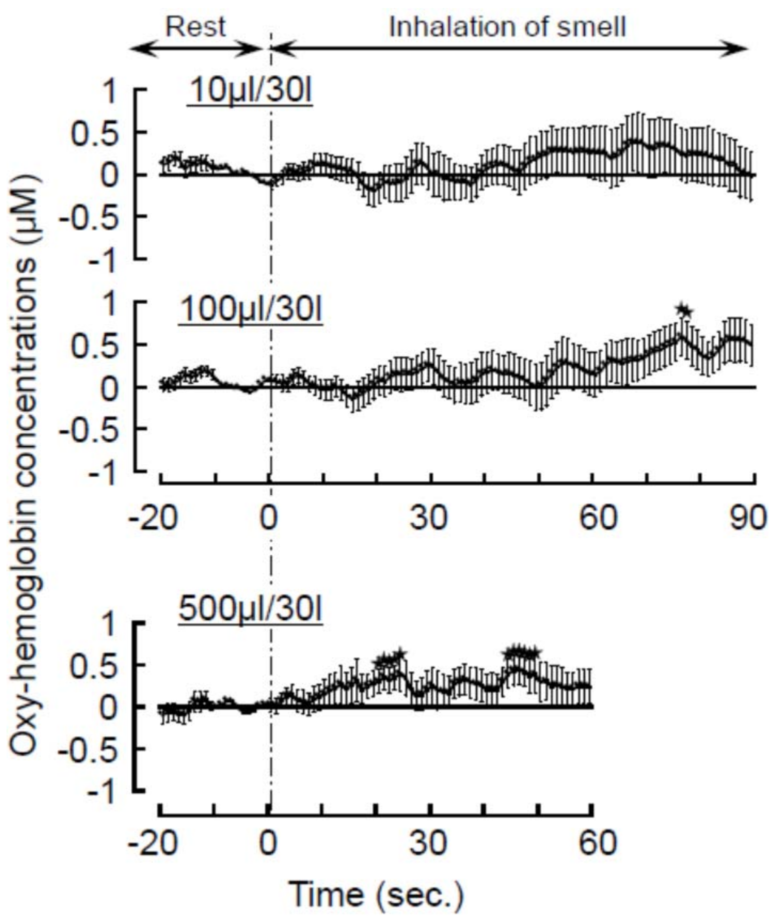

Figure 4. Time-course changes in prefrontal oxygenated hemoglobin concentration in response to inhalation of α-pinene at different concentrations (shown as deviations from the average values over 10 s before stimulation). Mean ± SD, N=15-17, * : $p<0.05$, ** : $p<0.01$ (compared to the average values over 10 s before stimulation).

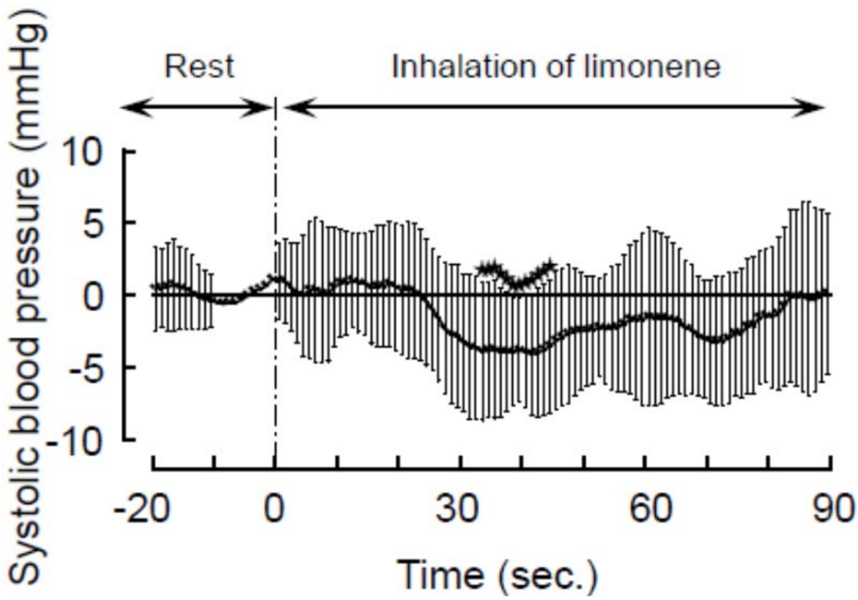

Figure 5. Time-course changes in systolic blood pressure in response to inhalation of limonene (shown as relative changes to the average values over 10 s before stimulation).Mean ± SD, N=17, * : $p<0.05$, ** : $p<0.01$ (compared to the average values over 10 s before stimulation).

Limonene is another common phytoncide of wood. It is also contained in citrus peel and has a lemony, grapefruit-like smell. Tsunetsugu et al. [24] demonstrated that limonene at a concentration of 10 μL/30 L emitted at a rate of 3 L/min from a position approximately 15 cm beneath the nose of subjects was evaluated as being "slightly comfortable" and "slightly soothing." Blood pressure started to decrease after 20 s from the commencement of inhalation; further, this decrease reached a significant level at 33–44 s (Figure 5). It was concluded that inhalation of limonene was experienced as comfortable and soothing and suppressed sympathetic nervous activity.

Bensafi et al. also investigated the effects of scents of pure compounds obtained from plants or trees [25]. The odors of six such compounds were presented (isovaleric acid, thiophenol, pyridine, L-menthol, isoamyl acetate, and 1-8 cineole) to 12 subjects. They examined whether there was a relationship between subjective reports and changes in the measured autonomic parameters, and found that skin conductance variation and arousal were positively correlated. Pyridine was rated as the least arousing compound and caused least skin conductance variation, whereas thiophenol was the most arousing compound and caused maximum variation in skin conductance. A negative correlation between heart rate and pleasantness was also found, i.e., when an odor was evaluated as being more pleasant, it caused less variation in heart rate. The authors mentioned that these may not be modality-specific responses because similar correlations have been reported in cases of visual and auditory stimulations.

Despite the large number of studies, it remains unclear to date whether odor affects human physiology through the olfactory pathway or via the blood-borne route in the form of chemical compounds. Buchbauer et al. reported that odorous compounds were observed in the serum of mice, though in low concentrations, after an inhalation of sedative odors [26].

Dayawansa et al. referred to both possibilities in their report [27]: they described that cedrol (the odorous compound used in their study) could act via the central olfactory and limbic systems, and/or via the blood-borne route or peripheral afferent fibers of the vagal nerve innervating the respiratory system. The most recent human study demonstrated that cedrol directly inhaled through the lower airway, but not introduced to the upper airway, caused a suppression of sympathetic outflow and an increase in parasympathetic outflow [28]. The other studies on scents of lavender, lemon, valerian, and so on, agreed with each other to a considerable extent on the fact that the effectiveness of odors such as prolonged pentobarbital sleep time [29, 30], lowered blood pressure [31], and suppressed renal sympathetic nervous activity [32] disappeared in anosmic mice or rats; this indicates the mediation of the olfactory system in the whole process. We consider that odors affect human physiology mainly through the olfactory processing pathway; however, in the case of laboratory experiments, the possibility that odorous compounds act directly via the blood-borne pathway could not be eliminated since the concentration of inhaled compounds is relatively high. In the case of actual forests where the odorous compounds (phytoncide) exist in very low atmospheric concentrations, it would be unlikely that phytoncide exerts its effects via the blood-borne route, but via the olfactory processing pathway.

Auditory Stimulation

Mishima et al. [33] compared the changes in brain activity and systolic blood pressure caused while listening to the sound of a turbine (dental implement) representing artificial sound, or the sound of a stream representing natural sound. No sound was introduced in the control session, i.e., the subjects heard no sound. Systolic blood pressure was significantly increased with the sound of the turbine; however, it was not changed by the sound of a stream. Prefrontal activity estimated by using the NIRS method was considerably reduced when listening to the turbine, while it showed a slight but significant decrease when listening to the stream. Brain activity is frequently enhanced when stress is perceived; however, in this case, the sound of a turbine was so unpleasant that the flight reaction might have been induced. In the “Null” session, systolic blood pressure and cerebral activity did not show significant changes. The study was conceived with a view to masking the alarming sound of a turbine with the gentle sound of a stream; however, further studies on individual differences in physiological response depending on age, dental experience, and other factors would be required in order to put this idea into practice.

Tactile Sensation

Among the elements of the forest environment, interior wood is considered to have the strongest association with tactile sensation. Sakuragawa et al. [34] compared the physiological changes caused by touching a metal plate and an oak plate and found that contact with the metal plate at 20˚C induced an increase in blood pressure while the wood panel caused little increase in blood pressure even on cooling to 5˚C. In the subjective evaluation, the cold oak was felt to be uncomfortable but natural; this probably explains the suppression of a blood pressure increase.

Miyazaki et al. [35] reported on the effects of painting. They compared changes in systolic blood pressure caused by touching Japanese cedar panels with no paint, with thin paint (oil finish), with thick paint (polyurethane paint), and a metal plate. In the case of no paint and thin paint, systolic blood pressure rose briefly and then rapidly fell back to baseline levels, whereas it remained high when the subjects touched the thickly painted panel and metal. These results indicated that cedar wood could be as much a stressor as metal when coated with a thick layer of paint. Wood is usually coated with paint for maintenance reasons; however, this tends to negate the comparative advantage of the material in terms of human-friendliness.

Conclusion

In this chapter, we have examined various physiological measurements that can be employed in laboratory experiments aimed at elucidating the effects of factors relating to the human senses. Recent technological progress has enabled precise non-invasive investigation of physiological responses. Various studies have revealed that the components of a forest environment, even if as a piece of stimulation, can affect human physiology in a favorable manner.

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Section 5. Green Areas and Human Health: Epidemiological Studies

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Chapter 15

Green Spaces and Population Health

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Abstract

This chapter looks at the potential for contact with natural environments to help solve key public health problems in economically developed nations. It begins by asking why public health is interested in natural environments, noting a current failure to tackle high prevalence of poor mental health and of chronic disease. The chapter then explores mechanisms and theories for how natural environments might affect health, before discussing both study designs and results from current literature. After exploring the weaknesses in the existing evidence, the chapter closes by proposing some key questions which need to be answered if the potential of natural environments to positively affect population health is to be maximised.

Keywords: public health, salutogenesis, mortality, morbidity, evidence

Introduction

Why are public health professionals interested in natural environments? Public health has a long and successful tradition of thinking about how the characteristics of where we live can influence our health [1]. In the early days of public health, theories about why some areas seemed to have a sicker population than others centred on miasma; ‘something in the air’ which hurt people. Then, with the discovery of how infectious disease spreads, public health paid attention to the conditions prevailing in some locations and their ability to foster disease vectors and increase vulnerability. In modern times, we identified that industrial and air

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pollution influences our health. Even today, there is great concern about obesogenic environments which fill us with calories but deny us opportunities to burn them off [2]. Thus, whilst public health as a discipline is quite used to thinking about how the environment influences our health, the general direction of this relationship has been negative; public health and epidemiology have tended to ask ‘what is it about some places that make people more likely to be ill or to die?’ [1]. This has been an extremely successful approach. In most places, in most economically developed countries, the physical environments we live and work in are sufficiently controlled and protected to minimise the harm from ‘environmental threats’.

Today’s Population Health Problems

What then are the challenges to public health in the economically developed world in the 21st century and how do these relate to physical environment? Relatively high rates of chronic diseases such as cancers and cardiovascular disease remain, though many of these have seen remarkably falls in recent decades, particularly when measured by mortality rate [3]. One reason for the persistence of cardiovascular diseases, and some cancers, is high and rising levels of obesity. Perhaps the greatest emerging problem however is an apparent mental health crisis. In the European Union area, for example, data suggest that 27% of the adult population experienced at least one mental disorder in the past year; an estimated 83 million people are affected [4]. In some countries, other manifestations of social and mental malaise are also rife and growing; high levels of violence, suicide and problems with substance abuse [5]. Whilst modern medicine reaches ever greater heights in its ability to diagnose and cure individual patients with acute or chronic disease, the medical manifestations of wider social and economic problems remain and increase [6]. Medicine can now grow certain body parts and organs in laboratories or even design some drugs for a specific user, but it seems unable to halt a rising tide of obesity, misery and self-harm.

This bleak situation provides the background for a shift in the way public health is thinking about ‘place’. Rather than considering the pathogenic aspects of where we live as the main focus of interest, some in the public health arena are starting to consider the salutogenic (or literally, health creating) potential of where we live [7-9]. Can aspects of our environment help keep us well, or even cure us if we are sick? Having salutogenic places at the heart of public health policies is gaining credence [10, 11].

Natural Environments as Salutogenic

How does this relate to nature and health? The notion that contact with natural environments might bring benefits to health and wellbeing is also longstanding. In some cases, ‘fresh air’ or ‘a walk in the countryside’ have even been accepted parts of treatment regimes. The rural location of sanitoria for patients with Tuberculosis, for example, was deliberate [12]. In the 21st century however, epidemiological attention is being paid to the potential which natural environments hold for tackling key public health problems. In the rest of this chapter, we will consider the theoretical and empirical underpinnings for the ideas that natural environments might be able to make a positive contribution to population health and set out some key questions that will need to be answered before nature's place in public health policy can be settled.

What Are Natural Environments?

There are numerous definitions of natural environments (also called green spaces). The Centres for Disease Control define them as "open, undeveloped land with natural vegetation" (http://www.cdc.gov/healthyplaces/terminology.htm); parks, forests, playing fields, river corridors and the like. It is important to note that most of the epidemiological evidence for health impacts of exposure to natural environments or green spaces is about urban populations. The reasons for this are discussed later.

How Might Contact with Natural Environments Affect Our Health?

Three significant mechanisms have been proposed by which natural environments might influence health [13]. The first is that green spaces provide an opportunity for, and encourage, physical activity. There is strong evidence that physical activity benefits health, both as a means of weight control, but also as an activity in itself [14]. Sedentary lifestyle is pervasive in the economically developed world. This is at least partly because of the ways in which our environments make it relatively easy for us not to be physically active, and relatively hard for us to be so, even if we want to. Roads with no pavements, dangerous streets, shopping or leisure activities which are car accessed or car based, and a whole host of screen-based entertainments in our homes are examples [15]. Having a park or woodland track nearby might offer the opportunity we need to take some exercise. Evidence about the extent to which green spaces do foster and encourage physical activity is somewhat mixed however [16, 17]. Some studies do find that populations with greater access to green spaces are more physically active, whilst others find no relationship [18]. Yet, it is true that some form of physical activity is often an inherent part of visiting a green space, even if that is limited to walking into the space and out again. So, perhaps green spaces are just good places to get some exercise, and that is good for you. The second is that green spaces may facilitate and foster social contact [19]. People go to spaces with friends and family and / or may meet them there. There is evidence that social contact may benefit health, directly through the psycho-neuro-endochrine impacts which social activity may have on the brain and body, or indirectly through the social, economic and practical support which it may lead to [20, 21]. So, perhaps green spaces are places to be social, and that is good for you.

The third mechanism is perhaps more difficult to grasp. This is the idea that visual or physical contact with green environments is beneficial to health in itself; that contact with nature acts on the mind and body, somewhat like a drug [22-24]. This mechanism is distinct from the first two because it suggests that the environment *itself* has an impact on health, not the activity facilitated by the environment. Let us separate our thinking about this mechanism into two parts; what happens, and why it happens.

What happens to us when we are exposed to natural environments? It appears that we experience psychological and physiological benefits. Bodies and minds which may be tired from incessant everyday demands are 'restored', physical and mental stress is reduced. There does appear to be a biological basis for these effects. The brain controls the rest of our body, including our stress response and immune / healing response [22]. When we perceive a natural environment it appears that the brain's reaction is to lower our levels of stress and increase our levels of healing. In simple terms, perceiving such environments is good for you. It also appears that being in such environments is restorative for our mental functioning. It is relaxing for the mind to be in such places, and as a consequence, a tired mind recovers its abilities to process and function. There is a considerable and growing body of experiment evidence for these physical and psychological effects from both laboratory and field [25-31].

Why do these effects happen? There are two key theoretical models which attempt to explain why these effects occur. Ulrich proposed the psychoevolutionary theory (PET) [24, 32]. Kaplan and Kaplan proposed the Attention Restoration Model (ART) [33, 34]. In essence, both models propose something quite similar; that there may be an evolutionary basis behind an innate human preference for natural environments which can be perceived without making too difficult demands on our attention, and whose perception has beneficial effects. ART is focused on the opportunity for recovery from attentional fatigue, which it sees as a consequence of having to continually strive to mentally focus on specific tasks. The 'fascination' prompted by natural environments, in contrast, requires no effort and does not lead to fatigue. ART suggests that natural environments are rich in stimuli which promote so-called 'soft' fascination. These features provoke just enough interest to hold attention, but not so much to as to exclude room for reflection. This allows mental 'restoration'. PET suggests that a favourable natural scene which is interesting and evokes positive affect, holds our attention and displaces negative thoughts, allowing stress levels to fall. Whilst the theories differ slightly, in general the idea is that we have an innate preference for, and derive benefits from, the opportunities to relax, rest and heal which natural environments provide.

The Difference between Effects on Individuals and Effects on Population Health

In theory, and as demonstrated in experiments, contact with natural environments can have profound impacts on an individual's mind and body. The aim of an experimental study however, is to isolate the impact of a particular exposure on an individual [35]. This means experiments are designed to offer certainty that any health effects observed during or after being exposed to natural environments were actually *caused* by those environments. To do this, experimental studies are closely controlled. They usually exclude people who aren't physically or psychologically well, may limit participants to a particular age group, and are often of short duration. Many experimental studies assess the health or attentional span of participants before, during and just after their controlled exposure to a natural environment; they detect short-term changes in mood, or physiology. Can we apply the findings from these studies to population health?

The health of populations is governed by a broad and powerful set of characteristics [36-39]. Population health is, of course, the aggregate of individual level risk. The health of individuals is determined by an incredible range of factors, operating at individual, local, regional, national and even international levels. These factors also include the exposures people have accumulated right through their lives (and even before they were born) [40]. This means the health of a population in a particular location such as a city or even neighbourhood is not only influenced by the social, economic and environmental circumstances in that particular location, but also by the social, economic and environmental circumstances which occurred in other places and at other times [41]. We cannot simply measure the association between the amount of natural environment in a location, and the health of the population there, and assume a directly causal connection. Nor can we take the results from a controlled experimental study and assume that the relationships identified between contact with nature and participants' health will always hold in a wider population.

Furthermore, links between the health-related outcomes which have been demonstrably influenced by green space in experimental studies (often short term measures of attention, mood, cardiovascular response and stress), and those which are of interest in population health (often life expectancy, mortality and chronic mental and physical morbidity), are questionable. Although the aspects of health which green spaces seem to affect (such as wellbeing, a lower level of stress and lower blood pressure) are associated with lower risk of stroke or heart attack, we know little about how long lasting the effects of contact with nature are, or if their repeated triggering (by, for example, walking in the woods once a week) results in long-term lowering of risk of chronic disease or poor mental health. Perhaps such beneficial effects of contact with nature are easily offset by other adverse life or environmental circumstances. The complexity grows when we consider that the degree to which health benefits might be gained from natural environments possibly varies from person type to person type [42].

This is why we also need observational studies with which to explore the connections between exposure to natural environments and population health. They allow us to ask important questions about the extent to which greater access or exposure to them is associated with the health of large numbers of people, with a wider variety of characteristics. They also offer an opportunity to consider longer term health consequences of access to natural environments. They complement the experimental approaches.

Evidence for Impacts on Population Health: Studies Designs and Findings

What *kind* of evidence is there about the associations between access to natural environments and population health? Broadly speaking, the evidence stems from studies of surveys and routinely collected data, such as those on mortality or morbidity rates. Large scale surveys are able to capture information about the social, economic, demographic and behavioural characteristics of large numbers of people. When information about the environments in which survey respondents live or visit is included, it becomes possible to explore associations between those environments and peoples' characteristics, behaviours and health. There have been several such large surveys and epidemiological studies [43-51].

Studies from the Vitamin G project in The Netherlands are a good example. The project joined objective GIS-based measures of access to green space around the home with data on self-reported health from large scale surveys and on morbidity from official registers [52]. Studies in the Vitamin G project uncovered associations between measures of access to green space and diverse health measures, after adjustment for potential socio-demographic confounders [43, 44, 51]. In contrast to the Vitamin G work, studies from the UK, USA and elsewhere have used the neighbourhood, or the population group within a small locality, as the unit of analysis, rather than the individual [46, 47, 53].

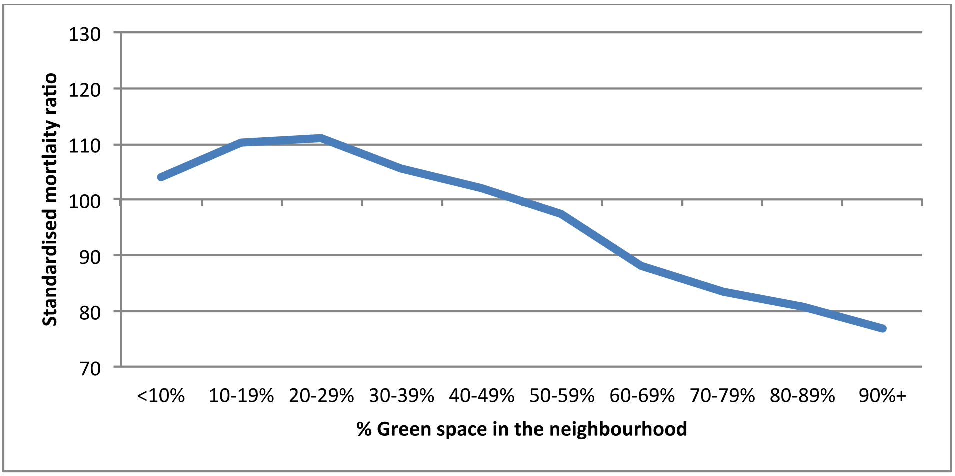
A weakness in all such studies is that it is impossible to reliably attribute *cause* in any observed associations [54]. For example, suppose that in a population health survey we see an association between an individual's access to natural environments and a lower risk of poor mental health. It might be that the individual does access the natural environment and this is indeed the direct cause of their relatively good mental health. However, it might equally well be that the individual's good mental health stems from other life circumstances such as the quality of their work or relationships, a good quality childhood, or social activities in a completely different arena to the natural environment. Furthermore, perhaps with such a good quality and productive life, they are able to afford residence in a pleasant, green neighbourhood. The fact that they have access to natural environments is thus not directly related to their good mental health at all.

A Broad Summary of Current Evidence

Bearing in mind the problems with observational studies, what are their findings? There is currently no systematic review which pulls together all the evidence available on the relationships between population health and access to green spaces (though see Bowler et al. a partial review of experimental evidence [55]). The summary below is very general and serves to communicate the broad nature and direction of the relationships which have been observed. Broadly speaking, there is an independent, positive association between the amount of green space in an urban area and the health of the population living there. An example of this relationship is shown in figure 1.

Figure 1 shows the pattern of association typically observed in many epidemiological studies; as access to green space in the neighbourhood increases, the risk of poor health falls. This relationship survives adjustment for socio-economic deprivation, air pollution and other potential confounders. Starting from this illustrative position, we are able to qualify the relationship in several ways.

The relationship holds for a variety of measures of health, mortality and morbidity, and especially for diseases of the circulatory, respiratory system and for mental health. It is not observed for health outcomes which are not plausibly related to contact with nature [47]. Some cancers, for example, have no element of stress or sedentary lifestyle in their aetiology and, as we would expect, we see no beneficial effect of green space on risk of these.



Source: original analysis of mortality data from England.

Figure 1. The relationship between mortality rates from cardiovascular disease and amount of green space in urban neighbourhoods in England, for population aged 30-64.

The graph shows the relationship for urban areas in England. It does appear that the presence and strength of this relationship varies from setting to setting and country to country. Whilst there are few comparable studies from countries outside northern Europe, Richardson et al. did not detect effects of green space on population health in New Zealand [49], and our own work in progress has found no relationship between the amount of green space in American cities, and their population health.

The strength of the relationship may well differ according to gender [48]. It does appear that the beneficial impacts of green space are felt more strongly by men than by women. It is not yet known if this is due to differences in duration, frequency and mode of contact with natural environments between the genders, or whether there are actual differences in the effectiveness of the biological mechanisms which may be triggered.

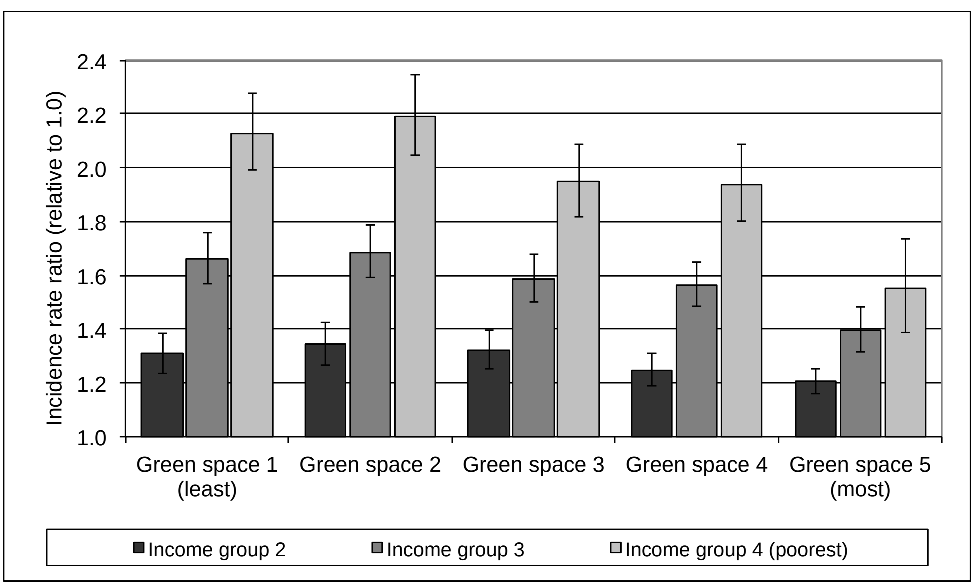
There is some emerging evidence from the UK that the effects of neighbourhood green space on health may be more profound for those with more deprived socio-economic circumstances.

Most research so far has focused on urban populations; there has been little investigation as to whether rural populations experience different associations with their natural environments (see [56]). There are good reasons for this. Much of the current research stems from northern Europe, which is highly urbanised (roughly 70% of the European population lives in cities, and an even greater proportion of the burden of disease in Europe is found in urban settings). Also, many studies have used quantity of, or distance to, green spaces as the measure of accessibility. In urban areas, much of the access to natural environments is provided by discrete and bounded parks or river corridors, making it straightforward to quantify access in this way, and appropriate. In rural areas though, the vast majority of the environment is ‘natural’, making it technically and theoretically difficult to measure ‘access’.

There is currently little or no evidence that greater access to natural environments harms population health, however (as noted above) there is evidence that its benefits are not evenly distributed and qualitative studies often reveal that some groups feel threatened or repelled by natural spaces [57]. There is currently little or no evidence about how the cost-effectiveness of natural environments as a means to improve or maintain population health compares with other approaches, such as health promotion campaigns or health service modifications.

Inequalities

There is a further finding from this field which is worthy of note. In 2008, Mitchell and Popham examined variation in health inequalities according to green space exposure [47]. They found that health inequality, that is to say the health 'gap', between more and less advantaged populations, is smaller among those with greater access to green space. Their results are illustrated in figure 2. The figure presents relative risk of cardiovascular disease mortality for 4 income-related groups; group 1 is the wealthiest and the reference category, groups 2-4 are successively and increasingly poorer. The income-related gap in health is well illustrated in 'green space group 1', those living in urban areas with the least amount of green space available to them. Among these populations, the poorest group has a cardiovascular disease mortality rate more than twice that of the richest. Among those living in urban areas with the most amount of green space (green space group 5) however, the gap is substantially and significantly smaller. The study design they employed could not provide evidence about how this lower level of health inequality occurs. The authors hypothesised that in an environment with little green space, access to opportunities for physical activity and restoration may require resources, such as money to buy gym membership or a car to go and visit more pleasant environments, and hence lead to a health disadvantage for poorer people. In an environment with lots of green space however, access to opportunities for restoration and physical activity are equalised.



Source: data from Mitchell and Popham 2008 (47)

Figure 2. Income related inequality in mortality from cardiovascular disease among urban populations in England, by quantity of green space in the neighbourhood.

This study has yet to be replicated with other health outcomes, or in other settings. However, the study findings are important since dealing with health inequalities in economically developed nations has proven exceptionally difficult.

Conclusion

Evidence suggests that populations who are exposed to and/or access natural environments are, broadly speaking, at lower risk of poor health. Experimental studies at individual level suggest that this could be a causal relationship, but proof of causal effects at a population level remains absent. What can we *do* with this knowledge? How useful is it for those concerned with public health?

It is important that natural environments appear to particularly affect diseases which are public health priorities; cardiorespiratory and mental health. Given that conventional medicine seems to have stalled in its ability to address such problems at a population level, this potential contribution of natural environments needs to be taken seriously. However, in many urban areas in economically developed countries, access to natural environments is actually pretty good. The public health problems we face today are still occurred among populations that already have good access to green spaces. The capacity to physically increase opportunities for access (i.e. more green spaces) may be limited and our attention may need to focus on increasing the amount of time people spend in these environments, (re)designing these environments to have maximum health benefits, and thinking more about what activities people undertake within the spaces.

From Evidence to Policy and Practice

Epidemiological studies have, so far, provided a comparatively shallow understanding of relationships between public health and access to natural environments. A particular weakness is a lack of information about how the type and quality of the natural environments might influence the effects which occur [13]. Furthermore, we still know relatively little about how the impacts of natural environments might vary by population type and setting. These weaknesses prompt a series of questions which the study of natural environments and population health should prioritise.

What should the configuration, design and mix of natural environments be to maximise population health benefits? This is an important question because its answer(s) will help guide the planning, design and promotion of green spaces within our urban areas. We do not know, for example, whether few large natural spaces in cities provide comparable or even greater benefits than a large number of small natural spaces. We do not know whether the configuration of the natural spaces is significant in determining the effects which occur. Should the space be natural in a loose sense, that is to say highly maintained and groomed, or as wild as possible, to achieve the maximum effects on health?

Who should we expect natural environments to affect most or least? Individual and wider environmental characteristics appear to affect the power of natural environments to protect or improve health. A more detailed understanding of this variation will lead us to more realistic expectations of what to expect from natural environments.

Finally, how strong can the effects of appropriately designed and managed natural spaces be on population health and how does the provision of natural environments compare to other forms of population health improvement for cost-effectiveness?

There is, as yet, insufficient knowledge for precise planning and land management practice to maximise potential benefits to population health from natural environments, or to provide robust expectations as to what might be achieved by them. Yet, the evidence which does exist offers hope that natural environments can be part of the means to tackle 21st century public health problems and inequalities.

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Chapter 16

The Beneficial Effects of Green Exercise on Health

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Abstract

Mental ill-health, obesity, physical inactivity and cardiovascular disease are all on the increase, along with a growing trend towards urbanised living. However, exposure to nature and greenspace positively affects health and well-being. Thus, some of these health challenges could be addressed by providing accessible urban and rural spaces for recreation and interaction with nature, also termed ‘green exercise’.

Engaging in green exercise activities has both direct and indirect health benefits. Direct benefits include both mental and physiological health gains. Green exercise improves self-esteem and mood, facilitates feelings of relaxation and enhances happiness. It also reduces blood pressure, heart rate, stress biomarkers, Body Mass Index (BMI), risks of all cause and circulatory disease mortality and improves immune function. The restorative function of nature, its aesthetic appeal and provision as a setting for green exercise also facilitates social contact, representing an indirect health benefit.

A number of different approaches have been shown to facilitate green exercise behaviour and thus have both direct and indirect benefits on health and social care. These include ‘green exercise therapy’ for vulnerable groups; introducing green education and different green exercise experiences at a young age; and encouraging green design to ensure maximal opportunities for green exercise. Evidence suggests that facilitated green exercise activities may have therapeutic applications, which may play a key role in managing and supporting recovery from mental ill-health. Experience of natural environments during childhood impacts upon adult behaviour. Therefore, increasing ecological knowledge in younger generations could well provide a means of heightening the interest of young people in their local environment and increasing outdoor engagement and green exercise activities throughout adulthood.

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Incorporating greenspaces into landscapes can also facilitate opportunities for green exercise and simply having access to green views can create a greater perceived level of restoration than no view or a view of a brick wall. Thus, these findings suggest that attention could be given to developing the use of green exercise as a therapeutic intervention, that planners and architects should improve access to green space (green design), and that children should be encouraged to spend more time engaging with nature and given opportunities to learn in outdoor settings (green education). Some of the substantial mental health challenges facing society and physical challenges arising from modern diets and sedentary lifestyles could be addressed by increasing green exercise participation.

Keywords: Green exercise, self-esteem, mood, blood pressure, green design, green education

1. Introduction

The term health is generally taken to incorporate physical health, mental or emotional health, social health, spiritual health, lifestyle and functionality. The World Health Organization definition of health is still the most widely cited and states that "health is a state of complete physical, mental and social (individual) wellbeing, and not merely the absence of disease or infirmity" (WHO, 1948). Positive mental health is not the same as a lack of ill health: it is about living life well (Huppert *et al.*, 2007). Positive emotions and well-being improve health and long-term survival (Huppert and Whittington, 2003, Ostir *et al.*, 2001). Mental ill-health costs society some £77 billion per year in the UK (Foresight, 2008). Common mental disorders affect 16% of the adult population at any given time. There are now 700,000 new dementia cases per year (equating to a cost of £17 billion). Under current circumstances these are predicted to rise to 1.4 million by 2040 (Foresight, 2008). Five million people are estimated to be stressed in the workplace, and the consequent physical and mental ill health results in a loss of 10% of GNP per year (Mind, 2005). Mental ill-health brings stigma, prejudice and discrimination, and is known to be carried forward from childhood to adulthood (Foresight, 2008).

It is well-known that physical activity improves both physical and mental health (CDC, 1996, Department of Health, 2004b, Foresight, 2007, Sandercock *et al.*, 2009). Exercise enhances quality of life (Brenes *et al.,* 2007, Dunn *et al.,* 2005), alleviates psychiatric and social disability (Richardson *et al.*, 2005) and reduces depressive symptoms (Tsang et al., 2008). It is also important for maintaining physical fitness, strengthening the immune system, increasing stress tolerance and preventing some of the diseases of affluence, such as cancer, heart disease, cardiovascular disease, type II diabetes, obesity and back pain (Department of Health, 2004a, Warburton *et al.*, 2006). Regular physical activity also improves the survival of the elderly and their quality of life (Lim and Taylor, 2004). Government is increasingly recognising the need to promote daily physical activity for health. In the UK, NICE (2009) has issued guidelines and Public Service Agreement (PSA) targets, and the Department for Schools, Communities and Families (2009) has published a new strategy for children and young people's health. Echoing the five pieces of fruit and vegetable recommendation for diets, individuals are now being encouraged to undertake at least five half-hour bouts of moderate physical activity per week, or 10,000 steps per day (approximately 4 miles) (Department of Health, 2004a).

In parallel with increasing mental ill-health, obesity, physical inactivity and cardiovascular disease is a growing trend towards urbanised living. More than half of the world's population now live in urban settlements and daily environmental contact with nature and greenspaces is becoming rarer (UNFPA, 2007). Nature is defined as 'the environment in which organisms or their biotopes expressly manifest themselves. In addition to nature reserves, this also includes farmland, production forest, urban green spaces and back gardens' (Health Council of the Netherlands, 2004). Nature's ecosystem services support human health and wellbeing in a variety of ways. These include the provision of resources for basic survival, such as clean air, water and genetic resources for medicines, along with the provision of raw materials for industry and agriculture. However, there is increasing evidence to show that exposure to nature and greenspace positively affects health and well-being by providing accessible urban and rural spaces for recreation and interaction with nature (Barton and Pretty, 2010, Hansen-Ketchum *et al.*, 2009, Maas *et al.*, 2006, Pretty *et al.*, 2006, Pretty *et al.*, 2007, Van den Berg *et al.*, 2007). Green settings also positively shape perceived health (De Vries *et al.*, 2003, Maas *et al.*, 2006, Mitchell and Popham, 2007, Sugiyama *et al.*, 2008), whether it involves passive or active engagement.

2. Green Exercise: The Synergistic Link between Nature and Activity

Natural ecosystems can provide an environmental setting for physical exercise or activities, also termed 'Green Exercise' (Bowler *et al.*, 2010, Pretty *et al.*, 2003, Pretty *et al.*, 2005). Both physical activity and exposure to nature have separately been demonstrated to provide benefits for mental well-being, thus green exercise has synergistic health benefits (Barton *et al.*, 2011, Barton *et al.*, 2009, Peacock *et al.*, 2007, Pretty, 2007b, Pretty *et al.*, 2007, Pretty *et al.*, 2005). The term green exercise incorporates all types of activities from walking to running, cycling, fishing, gardening, woodland or conservation activities to boating, skiing or mountain climbing. It also encompasses all types of green settings ranging from deep wilderness, open countryside, forests, woodlands, national or country parks, nature or wildlife reserves, urban parks, grasslands, hills and valleys to domestic gardens and allotments. Participating in these types of green exercise activities generates a number of health and social benefits:

1) Direct Positive Effects

   a) Mental Health - improves self-esteem and mood (Barton *et al.*, 2011, Barton *et al.*, 2009, Barton and Pretty, 2010, Hartig *et al.*, 1996, Hartig *et al.*, 2003, Pretty *et al.*, 2007, Pretty *et al.*, 2005, Ulrich *et al.*, 1991, Van den Berg *et al.*, 2003), increases feelings of relaxation (Park *et al.*, 2007) and enhances happiness (Van den Berg *et al.*, 2003).
   b) Physiological Health - reduces blood pressure (Hartig *et al.*, 2003, Li *et al.*, 2011, Park *et al.*, 2007, Pretty *et al.*, 2005), heart rate (Laumann *et al.*, 2003), reduces stress biomarkers (such as cortisol) (Hartig *et al.*, 1996, Park *et al.*, 2010, Van den Berg and Custers, 2010), reduces Body Mass Index (BMI) (Hine

et al., 2011), waist circumference and waist to hip ratios (Hine *et al.*, 2011, Sandercock *et al.*, 2009), levels of overweight and obesity (Ellaway *et al.*, 2005), risks of all cause and circulatory disease mortality (Mitchell and Popham, 2008) and improves immune function (Li, 2010, Li *et al.*, 2010, Li *et al.*, 2007).

2) Indirect Positive Effects

   a) Facilitates Social Engagement – Fosters social bonds and contributes to social capital (Coley *et al.*, 1997, Kuo *et al.*, 1998, Ward Thompson, 2002).

2.1. Mental Health Benefits

Engaging in green exercise has been shown to be more effective than comparable activities indoors (which reflect the exercise component only) (Thompson Coon *et al.*, 2011) or in urban spaces lacking green space (Pretty *et al.*, 2005). Green exercise is associated with decreased feelings of tension, confusion, anger and depression, whilst exhibiting greater feelings of revitalisation (Thompson Coon *et al.*, 2011). Outdoor experiences are rated as more restorative (Hug *et al.*, 2009) and more effective in improving mood and vitality (Ryan *et al.*, 2010). In comparison, indoor activity is associated with increased frustration, anxiety, anger and sadness (Teas *et al.*, 2007). In addition, walking in greenspaces is more effective at enhancing self-esteem and mood than walking indoors, suggesting a greater amalgamated health benefit than either component alone (Mind, 2007, Peacock *et al.*, 2007).

Participation in green exercise reduces stress, improves cognition and accelerates recovery from illness (Hansen-Ketchum *et al.*, 2009). Its restorative properties reduce brain activity and the associated effects that stress has on the mind (Berman *et al.*, 2008). Green exercise has also been shown to reduce state anxiety, with perceived greener settings producing the largest changes (Mackay and Neill, 2010). A lot of UK studies have focused on changes in self-esteem and mood after an acute bout of green exercise. Self-esteem and mood are important indicators of short- and long-term psychological wellbeing. Self-esteem refers to a positive or negative attitude towards the self and is an evaluation of a person's sense of worth or value (Blascovich and Tomaka, 1991). It is commonly accepted as a key indicator of emotional stability and is thus a contributor to mental wellbeing, quality of life and survival (Huppert and Whittington, 2003).

Mood is the host of "transient, fluctuating affective states" that can be both positive and negative (Hull, 1991). Mood is an integral component of daily life and has a strong influence on feelings of happiness, being able to appreciate the moment, being willing to help others, coping with stressful situations and general quality of life (Berger *et al.*, 2002). Mood is linked with physical health and is known to affect the immune system and healthy behaviours, and has the potential to affect the onset of specific diseases (Flory *et al.*, 2004, Melamed, 1995). Acute changes in mood are generally maintained for 2-4 hours post exercise (Raglin and Morgan, 1987, Thayer, 1996). However, this relatively short duration of enhanced mood has a positive influence on quality of life including more social interaction, improved productivity and better behavioural choices (Berger *et al.*, 2002). Engaging in regular exercise over the long-term can contribute to more sustained changes in mood. Positive mood increases serotonin levels (Flory *et al.*, 2004), and green exercise improves mood. In 2005 Pretty *et al* assessed changes in self-esteem and mood after exercising whilst viewing either pleasant or unpleasant urban and rural scenes. All exercise conditions led to a significant improvement in self-esteem, however the unpleasant settings reduced the positive effects of exercise, whilst the green scenes led to the greatest improvements (Pretty *et al.*, 2005). Mood was also significantly affected by viewing the different environments. Both the urban and rural pleasant green conditions led to significant reductions in fatigue and tension and a significant increase in vigour. Urban green scenes also led to a significant decrease in depression, highlighting the importance of nearby pockets of green space in urbanised areas.

Pretty *et al* (2007) also analysed the health benefits of participating in ten different green exercise activities, including walking, fishing, horse-riding, cycling and conservation activities, in four different regions in the UK. The results of the study found that green exercise led to significant improvements in self-esteem and mood, with significant improvements in the mood sub-scales of anger, confusion, depression and tension (Pretty *et al.*, 2007). Furthermore, improvements in self-esteem and mood were not affected by the type, intensity or duration of the exercise or the different regions.

Barton *et al* (2009) went on to assess the mental health effects of walking in four UK national heritage sites. Both self-esteem and overall mood significantly improved and feelings of anger, confusion, depression, fatigue and tension all reduced, providing a similar pattern of results. However, in contrast to the results of Pretty *et al* (2007), the study suggested that there was a relationship between the duration of green exercise and the degree of improvements in mood. Participants walking for the longest period of time displayed the greatest improvements in mood (Barton *et al.*, 2009). Thus, simple interventions such as a walk in the park at lunchtime or walking or cycling to work are likely to be effective in reducing stress and improving mental health.

2.2. Physiological Health Benefits

As both rural and urban green spaces facilitate opportunities for green exercise (Kaczynski and Henderson, 2007, Maas *et al.*, 2008), this leads to a greater calorie expenditure, which benefits physiological health via known benefits of physical activity (Richardson *et al.*, 2010). Green spaces also encourage longer periods of activity because the environmental stimuli diverts attention from indicators of fatigue and pain (Hansen-Ketchum *et al.*, 2009). Individuals living in very green areas are less likely to be overweight or obese (Ellaway *et al.*, 2005) and have a reduced risk of all cause and circulatory disease mortality (Mitchell and Popham, 2008). Green exercise has a significant impact upon heart rate indices and blood pressure. Walking in forest environments reduces diastolic blood pressure, heart rate and cortisol concentrations in comparison to city walks (Park *et al.*, 2007). Blood pressure values decrease due to reduced sympathetic nerve activity and increased parasympathetic nerve activity (Li *et al.*, 2011). In 2003 Laumann *et al* demonstrated that viewing natural scenes led to a significant reduction in heart rate and increase in R-R interval from the baseline level (Laumann *et al.*, 2003). However, viewing urban ecosystems did not significantly reduce the participant's heart rate. Mean arterial blood pressure is also significantly reduced as a result of green exercise in rural environments (Pretty *et al.*, 2005). However exercising in non green urban settings actually increases blood pressure measures relative to an exercise only control group (Pretty *et al.*, 2005). Thus, green exercise can have a relaxing effect on autonomic functions. Salivary cortisol has been used as a biomarker to identify changing stress levels according to the type of exercise environment (Townsend and Weerasuriya, 2010). A lot of this work involving reduced levels after exposure to forest environments is reported in more detail in the accompanying chapters (Li *et al.*, 2011, Park *et al.*, 2010). However, an additional study found that thirty minutes of gardening following a stressful mental challenge accelerated the reduction of cortisol to baseline values in comparison to a control group (Van den Berg and Custers, 2010). Thus, the findings imply that green exercise has the potential to restore cortisol levels, whereas non-green urban exercise may impede the restoration process due to a sustained elevation in cortisol post intervention. Green exercise may also affect immune function, with forest walking increasing natural killer (NK) cell activity (Li, 2010). Adrenaline, a known marker of SAM activation, measured from urine samples, showed simultaneous decreases over time, implying an increase in NK cell activity.

2.3. Green Exercise Facilitates Social Engagement

The restorative function of nature, its aesthetic appeal and provision as a setting for green exercise facilitates social contact (Maas *et al.*, 2009), fosters social bonds (Brugha *et al.*, 2003, Kawachi *et al.*, 1997, Pretty, 2007a, Takano *et al.*, 2002) and contributes to social capital. High levels of social capital can have a direct effect on markers of individual and community well-being (Kawachi *et al.*, 1997, Pretty and Ward, 2001, Wood and Giles-Corti, 2008). Social capital captures the idea that social interaction and social norms are an important part of the basis for sustainable livelihoods and communities (Pretty and Ward, 2001). Levels of social interaction can be directly influenced by ecosystems (Coley *et al.*, 1997, Ward Thompson, 2002). Modern urban ecosystems lacking space and natural settings tend to restrict social contact as individuals are not attracted to their surrounding environments and thus tend to stay indoors, away from others (Coley *et al.*, 1997). However, green space in urban areas, in the form of parks, tree lined streets and allotments can facilitate social contact and give rise to stronger neighbourhood ties (Coley *et al.*, 1997, Kuo *et al.*, 1998, Ward Thompson, 2002). The higher the number of trees and vegetation in an area, the more people that use it and the more time they spend within it (Coley *et al.*, 1997, Kuo *et al.*, 1998). Green spaces can also increase social engagement and interaction through conservation activities and initiatives (Parliamentary office of science and technology, 2007, Pretty and Smith, 2004). These activities can connect people in groups and networks and build stronger communities, particularly in urban areas where natural and woodland areas are continuously declining (Parliamentary office of science and technology, 2007, Pretty and Smith, 2004).

3. A 'Dose of Nature'

The findings generate questions regarding the optimal dosage of green exercise to experience the maximum health benefits? Barton and Pretty (2010) conducted a meta-analysis on the mental health outcomes of different types of green exercise, of various durations and intensities, in different green settings involving different age cohorts and genders.

Environments included woodland, forests, watersides, urban green areas, farmland and wild habitats with activities such as walking, horse-riding, sailing and gardening. Green exercise in all settings resulted in significant improvements in both self-esteem and mood; however those spaces with open water produced a significantly larger improvement in both indices. Furthermore, the greatest effects for self esteem and mood occurred within the first five minutes of activity, suggesting an immediate health benefit.

The meta-analysis also revealed that the effectiveness of the green exercise was influenced by its intensity (Barton and Pretty, 2010). For self-esteem, light intensity exercise produced the greatest improvements, deteriorating with an increasing intensity of exercise. A similar response was noted for mood, however the lowest effect was for moderate exercise, increasing once again for vigorous. With regards to the different age cohorts of participants, the meta-analysis revealed that the fewest health outcomes occurred for the elderly, whilst the greatest health gains were experienced by those with mental ill-health, suggesting that exercise in green spaces can be therapeutic for specific cohorts of people (Barton and Pretty, 2010). The optimal dose of green exercise may be dependent on many variables, but it is clear that both natural and urban environments provide the ideal setting to facilitate activity and afford greater health benefits.

4. Approaches Facilitating Green Exercise

A number of different approaches have been shown to facilitate green exercise behaviour and thus have both direct and indirect benefits on health and social care. These include 'green exercise therapy' for vulnerable groups; introducing green education and different green exercise experiences at a young age; and encouraging green design to ensure maximal opportunities for green exercise.

4.1. Acknowledging Its Therapeutic Properties: Green Care

Evidence suggests that facilitated green exercise activities may have therapeutic applications (Peacock *et al.*, 2007, Pretty, 2007b). This type of 'green exercise therapy' falls under the umbrella term of 'Green Care'. 'Green care is an inclusive term for diverse nature-based interventions that use the natural environment as a framework in which to create health and wellbeing benefits for vulnerable groups of people (Sempik *et al.*, 2010). In the UK there is a growing movement towards green care in many contexts ranging from social and therapeutic horticulture, animal assisted interventions, ecotherapy, green exercise therapies as a treatment option and care farming (Hine *et al.*, 2008, Sempik, 2007, Sempik *et al.*, 2002, Sempik *et al.*, 2003). Green care is different to green exercise, in that it is used as a therapy or specific intervention for targeted populations, including psychiatric patients, people with learning disabilities, disaffected youth and several other at-risk populations, whilst green exercise is more of a therapeutic experience (Hine *et al.*, 2008, Pretty, 2006).

Green exercise therapies may provide an effective treatment option for mild to moderate depression. Barton *et al* (2011) compared a new green exercise walking programme involving individuals experiencing a range of mental health problems to alternative group-based health promotion initiatives (a social club and a swimming group), which were already in existence. Participants attended one of the three programmes and sessions were held once a week for six weeks. Levels of self-esteem and mood improved after participating in a single session, however, the improvement was significantly greater in the green exercise group compared with the sedentary non-nature based social activities club. Dose responses showed that both self-esteem and mood levels improved over the six-week period and improvements were related to attendance in the green exercise group. Thus, membership of outdoor walking groups may play a key role in managing and supporting recovery from mental ill-health.

Similarly, Discovery Quest is a community based project which offers adults experiencing mental health difficulties the opportunity to be involved in an outdoor based therapy project. The six month project involves walking and camping in both local and more remote green and wild spaces (Hine *et al.*, 2011). Participants experienced a significant improvement in their wellbeing, self esteem and overall mood. They also reported a significant decrease in their BMI and over half saw a decrease in their waist to hip ratio (WHR). The experience significantly contributed to a range of important outcomes for the beneficiaries and for the wider communities of mental health and green care.

Wilderness therapy is described as an "experiential programme that takes place in wilderness or a remote outdoor setting" (Conner, 2007). Although it has been widely used in the US for many years, it is a relatively new concept in the UK. It is most commonly utilised with adolescents with behavioural problems (Barton *et al.*, 2010, Peacock *et al.*, 2008) and adults with mental ill health (Hine *et al.*, 2011). The UK 'TurnAround' project is an example of an early preventive alternative intervention which combines nature-based activities in wilderness settings together with mentoring and workshops. It targets vulnerable youth at risk and uses outdoor activities and wilderness experiences to break down the physical and emotional barriers that inhibit social competence and improve self-esteem. Participation in the nine month programme significantly improves self-esteem, overall wellbeing and reduces feelings of tension, anger and depression (Barton *et al.*, 2010). The project gives them a real sense of achievement and each participant feels valued and respected. They start to understand the importance of listening and communicating with respect and school attendance and classroom behaviour both improve. Thus, the findings imply that projects like this should be seriously considered as part of a reformed response to youth justice and antisocial behaviour.

4.2. Providing Green Education and Encouraging Childhood Experience

Experience of natural environments during childhood can have a profound impact upon adult behaviour. Though contact with nature at any age can derive a whole number of benefits for physical and mental health, contact with nature during youth can directly impact upon healthy adult behaviours. Research indicates that the frequency of visits to green places during childhood significantly correlates to the number of visits during adulthood (Pretty *et al.*, 2009, Ward Thompson *et al.*, 2008). Therefore a lack of experience of nature as a child may directly result in a lack of contact during adulthood.

In recent years, a significant decline in young peoples' understanding of the natural environment has been widely reported, particularly in urban areas of industrialised communities (Pyle, 2001, Pyle, 2003, King, 2003, Orr, 2002, Pilgrim *et al.*, 2008). A number of reasons have been put forward to explain this decline, including a reduction in the number and accessibility of green spaces, more classroom-based learning and less outdoor-learning opportunities (more textbooks and less butterfly nets; (Pyle, 2001)), and busier lifestyles leading to fewer countryside visits with family members. These all culminate in the phenomenon Pyle describes as the 'extinction of experience', whereby children are experiencing nature far less than ever before in history. As a consequence, they are unfamiliar with nature's many components. Being able to recognise and name something (e.g. a tree or bird species) is a prerequisite to forming a bond with it and, thus, caring about it. Consequently, they act less to protect the species with which they are unfamiliar and further species loss and environmental destruction can continue unnoticed and unabated. This downward spiral of disconnection and disassociation can begin in childhood and continue through to adulthood.

Studies have identified a strong correlation between ecological knowledge and frequency of visits to green spaces (Pilgrim *et al.*, 2007). It is hard to determine the direction of this relationship (e.g. whether heightened knowledge leads to an increased number of outdoor visits or vice versa), but it is likely to be bi-directional. In the past local ecological knowledge was taught in schools. Today, however, global ecological issues such as climate change and regional biodiversity loss take precedence in the school curricula over local species and habitats. Studies have shown that knowledge of the local environment is most successfully transferred orally, between friends and family members (King, 2003, Pilgrim *et al.*, 2007). People who acquire ecological knowledge in this way often go on to pursue outdoor hobbies and careers, with subsequent health benefits. Therefore, increasing ecological knowledge in younger generations could well provide a means of heightening the interest of young people in their local environment and increasing outdoor engagement and green exercise activities throughout adulthood.

Evidently the type of environment has a profound effect on the type of play or activity initiated. Time spent in 'wild' nature such as hiking and playing in the woods has been shown to have more positive long term effects on children than time spent in 'domesticated' nature such as picking flowers, planting seeds or trees (Wells and Lekies, 2006). It has been suggested that the structure of 'domesticated' outdoor activities may hinder the experience by not allowing for "*extensive, spontaneous engagement with nature*" (Kellert, 2002) and so do not have such profound influence on the individual.

4.3. Encouraging Green Design

Incorporating greenspaces into landscapes can facilitate opportunities for green exercise and simply having access to green views can create a greater perceived level of restoration than no view or a view of a brick wall (Felsten, 2009). Exposure to urban non-green environments reports significantly higher prevalence of psychiatric, mood (depression) and anxiety disorders in comparison to green settings (Peen *et al.*, 2010). Associations between the presence of nature on urban estates and reduced crime rates are also reported (Kuo and Sullivan, 2001a, Kuo and Sullivan, 2001b, Kuo *et al.*, 1998). Thus, epidemiological studies often show associations between proximity to green space from the home and positive health outcomes (De Vries *et al.*, 2003, Grahn and Stigsdotter, 2003, Takano *et al.*, 2002).

Usage of green spaces is also important. The more frequent the visits, the lower the incidence of stress-related illnesses (Grahn and Stigsdotter, 2003). Having access to a public or privately owned garden adjacent to their place of residence was another principal factor, which has implications for both policy and urban landscape planning (Maas *et al.*, 2006, Mitchell and Popham, 2007, 2008). Tree-lined streets, parks and other green spaces play a key role in longevity and decreased risk of mental ill-health of residents of Tokyo, Japan (Takano *et al.*, 2002). This longitudinal study compared access to local walkable green spaces and mortality rates in elderly people over a period of five years. After controlling for demographic and socioeconomic variables, they found that out of 3100 Tokyo citizens born between 1903 and 1918, 71% were still alive in 1992 and the probability of living for an additional five years was linked to their ability to walk in a local park or tree lined street (Takano *et al.,* 2002). However, it is also important to acknowledge potential selection or causation mechanisms (De Vries *et al.*, 2003). Selection processes would suggest that healthy people move to green surroundings (selective migration), whereas causation mechanisms would imply that living in green environments promotes good health and wellbeing.

Perceived neighbourhood greenness is also strongly associated with better mental and physical health. Respondents who perceived their neighbourhood as highly green were 1.37 and 1.60 times more likely to have better physical and mental health respectively, in comparison with those who perceived it as low in greenery (Sugiyama *et al.,* 2008). The degree of species richness in urban green spaces has also been positively associated with psychological wellbeing of visitors (Fuller *et al.*, 2007), emphasising the importance of locally managed biodiversity for sense of place and reflection.

Health outcomes depend on both the types of green environments, and the services they provide, as well as the choices available to and made by people. If individuals do not engage with the natural world, either by observation or undertaking in physical activity in rural or urban green space, then they will not derive the mental or physical health services from ecosystems specifically. Such choices are affected by location of dwelling, proximity of and access to greenspace, and individual choices and environmental behaviours (DCSF/DH, 2009). Access to greenspaces is not equivocal and often varies according to cohort demographics. For example, highly educated and wealthy individuals are able to access certain environments more readily because they own a car. Often the most biodiverse settings are not served by public transport, which excludes the poorest individuals and other minority groups.

Thus, access is dependent on the socio-economic characteristics of the potential beneficiaries and not solely on the environmental qualities. Yet, having access to nearby greenspace can eradicate the health inequality levels in areas of deprivation (Mitchell and Popham, 2008). This highlights the importance of providing health promoting accessible greenspaces to reduce socioeconomic health inequalities. The health outcomes are thus not independent of people's demographics, choices and behaviours. Behaviours can also influence correlative relationships identified between greenspace exposure and health outcomes, which contributes to the challenge of interpreting the causal structure. Health benefit is thus a function of the environment type, ease of access and frequency of use.

Conclusion – Government Policies

There are many possible policy actions that can be used to encourage widespread change (Matson-Koffman *et al.*, 2005), but these tend to assume that an intervention will lead to permanently changed behaviours. Simple prescriptions, such as “move more, eat a little less”; “use the stairs, park a little further away”, may help to raise public awareness, but they do not guarantee outcomes at the population level (Norman and Mills, 2004). Increased provision of school PE and outdoor play is known to help, as are after-school programmes (Romero, 2005). Again, though, if such programmes cease because of lack of funding, there is no certainty that behaviour will not revert. Transport policy is similarly hard to change, as the motor car has become central to most people’s mobility (Smith and Bird, 2004). In Finland, for example, progressive policies increased participation in recreational physical activity in all age groups, especially around sports and the outdoors (Vuori *et al.*, 2004). But participation in cycling and walking fell, as these were affected by different factors and policies.

Many of the effects of unhealthy behaviours are reversible, and it is never too late to gain the benefits of change (e.g. walking for the elderly) (Fisher and Li, 2004). Cardiac rehabilitation programmes that include physical activity increase survival and reduce re-hospitalisation, but tend also to need social support, a positive environment, and personal motivation amongst participants to continue the behaviour (Fleury *et al.*, 2004). Breast cancer rehabilitation with regular exercise (30 mins walking five times a week) and increased fruit and vegetable consumption doubles the survival rate after 5-11 years (Pierce *et al.*, 2007), with the death rate falling from 14% to 7% for those with the healthy lifestyles.

It is also clear that rehabilitation of degraded natural habitats works and pays – it results in an increase in the number of visits and people then stay longer (Barton *et al.*, 2009, Evenson *et al.*, 2005). In a similar way, engagement with the national forest has been shown to change attitudes and establish new and important memories (Morris and Urry, 2005, Ryan and Grese, 2005). There are thus good economic reasons for protecting existing green spaces and rehabilitating other places to increase access and use. The costs and benefits of bike and pedestrian trails in Nebraska have been assessed: per capita costs are $209 per year, but medical benefits are $564 per capita, giving a cost-benefit ratio of 2.94. This suggests that these kinds of investments are worthwhile. In the UK, an analysis of the Walking the Way to Health Initiative’s 500 local schemes has recently shown that if all the population of England were afforded good access to green space and walked regularly, then there would be a saving to the health service of £2 billion annually (Natural England, 2009a).

Some 15% of GPs now use exercise referral schemes (there are estimated to be 1300 across country) (Mental Health Foundation, 2005), but many remain convinced they are ineffective. In the UK, 92% of GPs use anti-depressants as their most common treatment for mental ill-health. However, there are signs of change, with the Department of Health calling for a well at work scheme (Department of Health, 2009), and Natural England calling for a focus on the values of the Natural Health Service to complement the established National Health Service (Natural England, 2009b). In short, Active Living policies (Sallis *et al.*, 2006) need to be integrated into all aspects of public policy.

These findings suggest that attention could be given to developing the use of green exercise as a therapeutic intervention (Haubenhofer *et al.*, 2010, Hine *et al.*, 2009), that planners and architects should improve access to green space (green design), and that children should be encouraged to spend more time engaging with nature and given opportunities to learn in outdoor settings (green education). Some of the substantial mental health challenges facing society (Foresight, 2008, HSE, 2008) and physical challenges arising from modern diets and sedentary lifestyles (DCSF/DH, 2009, Department of Health, 2004b, NICE, 2008, 2009, Sport England, 2006, Wanless, 2002, Wanless, 2004, Wells *et al.*, 2007) could be addressed by increasing physical activity in natural places, particularly forests. If children are encouraged and enabled to undertake more green exercise, then they are more likely to have active exposure to nature embedded in their lifestyle as adults and will reap the associated health benefits.

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Chapter 17

Effect of Forest Coverage on Standardized Mortality Ratios of Cancers in Japan

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Abstract

We previously found that forest environments significantly increased human natural killer activity, suggesting the preventive effect of forest environments on cancer. To explore whether forest coverage affects the rate of deaths due to cancers in Japan, we investigated the relationships between the percentage of forest coverage and standardized mortality ratios due to cancers in all prefectures in Japan. Data on the percentage of forest coverage in all prefectures in Japan were collected from the database of the Forestry Agency of Japan. Data on standardized mortality ratios (SMR) due to lung, stomach, kidney, and colon cancers in males and females, breast and uterine cancers in females, and prostate cancer in males, and data of smoking status of males and females in all prefectures in Japan were collected from the database of the Ministry of Health, Labor, and Welfare of Japan. Human development index was used as a parameter of the socioeconomic status of each prefecture. The correlation and partial correlation coefficients between the percentage of forest coverage and SMR of cancers, after controlling for the effects of smoking and the socioeconomic status, were calculated. People living in areas with lower forest coverage had significantly higher SMR of cancers compared with the people living in areas with higher forest coverage. There were significant inverse correlations between the percentage of forest coverage and the SMR of lung, breast, and uterine cancers in females, and the SMR of prostate, kidney, and colon cancers in males in all prefectures in Japan, even after the effects of smoking and socioeconomic status were factored in. Taken together, these findings indicate that increased forest coverage may partially contribute to a decrease in mortality due to cancers in Japan.

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Keywords: breast cancer, colon cancer, HDI, kidney cancer, percentage of forest coverage, prostate cancer, SMR, uterine cancer

Introduction

A forest bathing trip, called "Shinrinyoku" in Japanese, involves a visit to a forest area for the purpose of relaxation and recreation by breathing in volatile substances, called phytoncides, released from the trees. The conception of forest bathing was first proposed in the 1980s and has become a recognized relaxation activity in Japan [1-10]. Since forests occupy 67% of the land in Japan [11, 12], forest bathing is easily accessible. According to a public opinion poll conducted in Japan in 2003, 25.6% of respondents had participated in a forest bathing trip, indicating its popularity in Japan [13]. Moreover, forest bathing is possible in similar environments throughout the world. We reported previously that phytoncides such as alpha-pinene, 1,8-cineole, and d-limonene extracted from trees significantly enhanced human natural killer (NK) activity and intracellular levels of perforin, granulysin (GRN), and granzymes A/B (GrA/B) in human NK cells both *in vitro* [14] and *in vivo* [15]. Komori et al., [16] also reported that citrus fragrance found in forests affects the human endocrine and immune systems as analyzed by the measurement of urinary cortisol and dopamine levels, NK activity, and CD4/8 ratios. These findings suggest that forest bathing may have beneficial effects on human immune function. Thus, we investigated the effect of forest bathing trips on human NK activity, and found increased human NK activity, NK cell numbers, and intracellular levels of perforin, GRN, and GrA/B in peripheral blood lymphocytes [1-6]. Moreover, we also found that the increased NK activity, number of NK cells, and intracellular anti-cancer proteins induced by a forest bathing trip lasted more than 7 days, even 30 days, after the trip both in males [2, 4] and females [3]. It is well known that the immune system including NK cells plays an important role on the defense against bacteria, viruses and tumors. People with higher NK activity showed a lower incidence of cancers, whereas people with lower NK activity showed a higher incidence of cancers [17], indicating the importance of NK cell function on cancer prevention. In addition, patients with an advanced performance status had significantly fewer granulysin-positive NK cells than healthy controls; impaired expression of granulysin by NK cells correlates with progression of cancer, and determination of granulysin expression might prove informative for assessing the immunological condition of cancer patients, indicating the importance of granulysin on cancer progression [18]. Therefore, cytolytic molecules such as perforin, GRN, and GrA/B contribute to anti-tumor activity [19, 20]. These findings suggest that forests may have anti-cancer effects by enhancing human NK activity and partially contribute to decreased rates of death due to cancers. These findings also encouraged us to propose a hypothesis that people living in areas with higher forest coverage may show lower mortality due to cancers; thus, we investigated the relationship between the percentage of forest coverage and standardized mortality ratios (SMR) due to cancers in all prefectures in Japan to verify this hypothesis [11]. SMR measures the level of excess or deficit in mortality in a study population compared with the expected level based on the mortality of a standard population. SMR is computed as the ratio of the observed deaths to the expected deaths in the study population. The expected deaths are obtained by multiplying the age-specific mortality rate of a chosen standard population by the age-specific population size of the study population and then adding terms to get the total expected number of deaths [21].

Materials and Methods

Data of the percentage of forest coverage in all prefectures in Japan in 2002 were collected from the database of the Forestry Agency of Japan [11, 12]. Data of standardized mortality ratios (SMR) of lung, stomach, kidney, and colon cancers in males and females, and SMR of breast and uterine cancers in females and prostate cancer in males in all prefectures in Japan in 1998 and 1999 were collected from the database of the Ministry of Health, Labour, and Welfare of Japan [11, 22]. We used the mean SMR of cancers in 1998 and 1999 for all cancers in the present study. Since smoking status influences the SMR of cancers [23-29], especially for lung cancer [23-25], data on the smoking status in males and females in 2003 were also collected from the database of the Ministry of Health, Labor, and Welfare of Japan [11, 30]. Since socioeconomic status is also a risk factor for cancers [31-34] we have to take it into account. The human development index (HDI) is a composite score used by the United Nations Development Programme to rank countries in terms of their human socioeconomic development status [35], which is a composite index of life expectancy, literacy, and per capita gross domestic product that measures the socioeconomic status of a country [36]. HDI has been used to estimate infant and maternal mortality rates around the world and assessed how well the HDI and its individual components predicted infant and maternal mortality rates for individual countries [36]. In the present study, we used HDI as a parameter of socioeconomic status in each prefecture [11, 37]. We first calculated the correlation coefficients between the percentage of forest coverage and SMR of cancers. Then, if the correlations were significant, the partial correlation coefficients between the percentage of forest coverage and SMR of cancers after factoring in the effects of smoking and socioeconomic status were also calculated.

Statistical Analysis

The correlation and partial correlation coefficients were calculated and an unpaired t-test was performed using the SPSS 14.0 software package for Windows. The significance level for p values was set at < 0.05.

Results

Effect of Forest Coverage on the SMR of Cancers

To investigate the effect of forest coverage on the SMR of cancers, we grouped the SMR of cancers by forest coverage (≤60% or >60%) in females (Figure 1) and males (Figure 2) in all prefectures in Japan. As shown in Figure 1, there were significant differences in SMR of lung cancer, breast cancer, uterine cancer, and the mean SMR of 6 kinds of cancers (lung, breast, uterine, stomach, kidney and colon cancers) between the forest coverage ≤60% and >60% in females. As shown in Figure 2, there were significant differences in SMR of prostate cancer, colon cancer, and the mean SMR of 5 kinds of cancers (lung, prostate, stomach, kidney and colon cancers) between the forest coverage ≤60% and >60% in males. These findings indicate that people living in areas with lower forest coverage had significantly higher SMR of cancers compared with the people living in areas with higher forest coverage.

Correlation between the Percentage of Forest Coverage and SMR of Cancers

To further explore the contribution of forest coverage to SMR of cancers, we calculated the correlation between the percentage of forest coverage and SMR of cancers. As shown in Tables 1 (females) and 2 (males) [11], there were significant inverse correlations between the percentage of forest coverage and SMR of lung (r=-0.455, p<0.001), breast (r=-0.530, p<0.0001), and uterine cancers (r=-0.328, p<0.05) in females, and SMR of prostate (r=-0.315, p<0.05), kidney (r=-0.348, p<0.05), and colon cancers (r=-0.299, p<0.05) in males. On the other hand, there was no significant correlation between the percentage of forest coverage and SMR of stomach, kidney, and colon cancers in females and lung and stomach cancers in males.

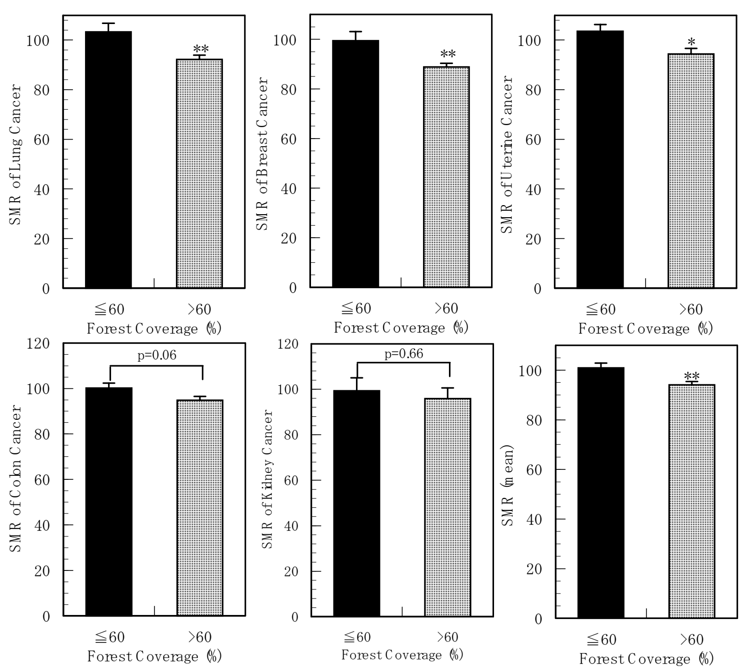

Figure 1. The SMR of cancers grouped by percentage of forest coverage of each prefecture in Japan in females. Data are presented as the mean+SE (n=15 for the percentage of forest coverage of ≦60%, n=32 for the percentage of forest coverage of >60%) *: p<0.05, **: p<0.01, significantly different from the percentage of forest coverage of ≦60%, respectively, by unpaired t-test.

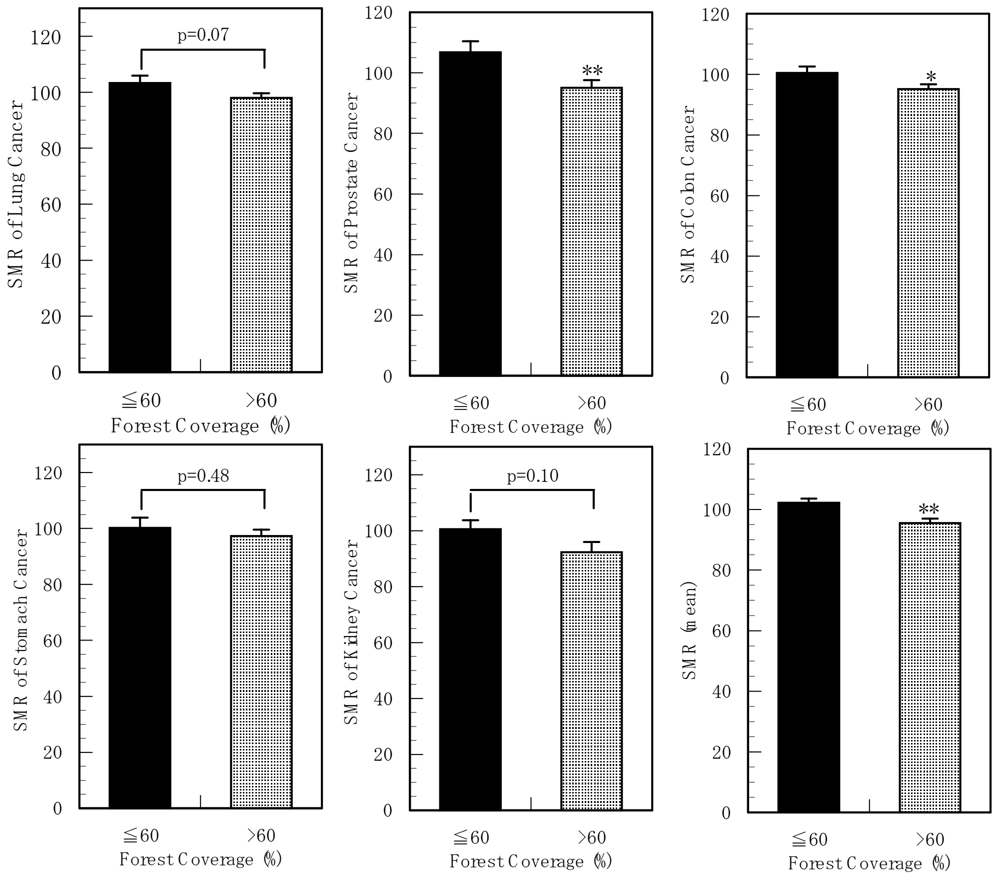

Figure 2. The SMR of cancers grouped by percentage of forest coverage of each prefecture in Japan in males. Data are presented as the mean+SE (n=15 for the percentage of forest coverage of ≦60%, n=32 for the percentage of forest coverage of >60%) *: p<0.05, **: p<0.01, significantly different from the percentage of forest coverage of ≦60%, respectively, by unpaired t-test.

Table 1. Correlation and partial correlation coefficients between the rate of forest coverage and SMR of cancers in all prefectures of Japan corrected by smoking rate and HDI in females [11]

Female	Correlation coefficients	Partial correlation coefficients1#	Partial correlation coefficients2#	Partial correlation coefficients3#
Lung Cancer	-0.455**	-0.304*	-0.468**	-0.325*
Breast Cancer	-0.530**	-0.312*	-0.501**	-0.308*
Uterine Cancer	-0.328*	-0.269	-0.377*	-0.293*
Stomach cancer	-0.050	0.027	0.008	0.048
Colon Cancer	-0.271	-0.101	-0.247	-0.099
Kidney cancer	-0.136	-0.078	-0.102	-0.068

*: p<0.001, **: p<0.001.

1#: corrected by smoking rate, 2# corrected by HDI, 3#: corrected by both smoking rate and HDI.

Table 2. Correlation and partial correlation coefficients between the rate of forest coverage and SMR of cancers in all prefectures of Japan corrected by smoking rate and HDI in males [11]

Male	Correlation coefficients	Partial correlation coefficients1#	Partial correlation coefficients2#	Partial correlation coefficients3#
Lung Cancer	-0.214	-0.207	-0.258	-0.251
Stomach cancer	-0.146	-0.131	-0.120	-0.100
Prostate cancer	-0.315*	-0.309*	-0.351*	-0.345*
Kidney cancer	-0.348*	-0.342*	-0.334*	-0.327*
Colon Cancer	-0.299*	-0.293*	-0.312*	-0.311*

*: p<0.05.
1#: corrected by smoking rate, 2# corrected by HDI, 3#: corrected by both smoking rate and HDI.

Partial Correlation Coefficients between the Percentage of Forest Coverage and SMR of Cancers after the Effects of Smoking and Socioeconomic Status Were Factored in

Since smoking status influences the SMR of cancers [23-29], and there was a significant positive correlation between the SMR of lung cancer and smoking rates in each prefecture in females, we further calculated the partial correlation coefficients between the percentage of forest coverage and SMR of cancers after the effect of smoking was factored in. As shown in Tables 1 and 2 [11], there were still significant inverse relationships between the percentage of forest coverage and SMR of lung ($r=-0.304$, $p<0.05$) and breast ($r=-0.312$, $p<0.05$) cancers in females, and SMR of prostate ($r=-0.309$, $p<0.05$), kidney ($r=-0.342$, $p<0.05$), and colon cancers ($r=-0.293$, $p=0.05$) in males after the effect of smoking was factored in. Socioeconomic status also affects the mortality rate due to cancers [31-34], and HDI has been used to evaluate the socioeconomic status of countries [35]. We further calculated the partial correlation coefficients between the percentage of forest coverage and SMR of cancers after the effect of socioeconomic status (HDI) was factored in. As shown in Tables 1 and 2 [11], there were still significant inverse relationships between the percentage of forest coverage and SMR of lung ($r=-0.468$, $p<0.001$), breast ($r=-0.501$, $p<0.001$), and uterine ($r=-0.377$, $p<0.05$) cancers in females, and SMR of prostate ($r=-0.351$, $p<0.05$), kidney ($r=-0.334$, $p<0.05$), and colon cancers ($r=-0.312$, $p<0.05$) in males after the effect of socioeconomic status was factored in. Moreover, there were still significant inverse relationships between the percentage of forest coverage and SMR of lung ($r=-0.325$, $p<0.05$), breast ($r=-0.308$, $p<0.05$), and uterine($r=-0.293$, $p=0.05$) cancers in females, and SMR of prostate ($r=-0.345$, $p<0.05$), kidney ($r=-0.327$, $p<0.05$), and colon cancers ($r=-0.311$, $p<0.05$) in males after the effects of smoking and socioeconomic status were factored in, suggesting that forest coverage indeed affects the SMR of cancers.

Discussion

We found previously that a forest bathing trip increased human NK activity, number of NK cells, and intracellular levels of perforin, GRN, and GrA/B in PBL [1-7]. Moreover, we also found that the increased NK activity, number of NK cells, and intracellular anti-cancer proteins induced by a forest bathing trip lasted more than 7 days, even 30 days, after the trip [2-4]. On the other hand, a city tourist visit to an area without forests did not affect human NK activity [2]. Increased NK activity and intracellular anti-cancer proteins contribute to anti-tumor activity [17-20]. This suggests that forests may have a preventive effect on cancer development and contribute to a decreased rate of death due to cancers. These findings also encouraged us to propose a hypothesis that people living in areas with higher forest coverage may show lower mortality due to cancers. The present study indicated that there is a significant inverse correlation between forest coverage and SMR of cancers, and that people living in areas with higher forest coverage show a significantly lower SMR of cancers compared with people living in areas with lower forest coverage. This may be important in health promotion and preventive medicine. Mitchell and Popham also reported that people exposure to green space including forests significantly lower the mortality from all causes and circulatory disease, supporting our findings [38].

Cigarette smoking is an important risk factor for lung [23-25] and stomach cancers [23, 26] and smoking increases the risk of breast cancer among women [27]. Gong et al. [28] also reported that smoking at the time of diagnosis, independent of key clinical prognostic factors, is associated with an increased risk of prostate cancer death. Both cigarette smoking and socioeconomic status are risk factors for kidney cancer [29]. Socioeconomic status is a risk factor for uterine cancer by affecting the utilization of efficacious screening tools in the early detection of the disease [32]. Therefore, the effects of smoking and socioeconomic status have also to be factored in. Thus, we further analyzed the partial correlation between forest coverage and SMR of cancers and found significant inverse correlations between forest coverage and SMR of cancers even after the effects of smoking and the socioeconomic status was factored in, suggesting that forests indeed decrease the mortality due to cancers in Japan.

The percentage of forest coverage correlated significantly with the SMR of lung cancer in females, but not in males, whereas, the forest coverage correlated significantly with the SMR of kidney and colon cancers in males, but not in females. Although we can not exactly explain the difference between genders, the higher average smoking rate in males (33.1%) than in females (6.4%) [30] may have a larger influence on the SMR of lung cancer than the effect of forest coverage, and the effect of forest coverage on lung cancer was less significant than the effect of smoking. It is well known that smoking increases the risk of lung cancer [23-25]. However, there was no association between cigarette smoking and the risk of colon cancer [23]. It is still difficult to explain the difference in the effect of forest coverage on kidney and colon cancers between genders. The percentage of forest coverage correlated significantly with the SMR of breast and uterine cancers in females, and the SMR of prostate cancer in males. Although we can not exactly explain the mechanism, sex hormones may partially contribute to this difference.

The percentage of forest coverage had no effect on the SMR of stomach cancer in either males or females. It is well known that certain bacteria increase the risk of stomach cancer [39]. In areas where gastric cancer is highly prevalent, such as Japan, Korea, and China, the great majority of gastric cancers are *Helicobacter pylori*-related. In Japan, the cumulative gastric cancer incidence rate of 0–84-year-olds was estimated to be 21.2% for infected males and 8.0% for infected females, under the conditions that half of the population is infected and infected people have a five-time higher risk of gastric cancer than uninfected people [40]. These findings suggest that *H. pylori* infection [39] and dietary habits [41] have more effect on stomach cancer than the effect of forest coverage, and the effect of forest coverage on stomach cancer was less significant than the effect of other factors such as *H. pylori* infection and dietary habits.

There are several limitations in the present study [11]. One is the use of information on smoking in 2003, whereas the data of SMR of cancers refer to 1998-99. Unfortunately, we could not obtain the data of SMR of cancers and the smoking rates for the same year; therefore, the use of 2003-related information on smoking as an adjusting factor for the correlations currently assessed should be an approximate indication of the smoking rate. However, the smoking rate should not change much during 1998-2003 in Japan. Many factors could influence SMR of cancers, and we only calculated the confounding effects of smoking and socioeconomic status in the present study. Other confounding factors should also be considered; therefore, further studies are necessary to assess more specific information.

In summary, the present findings suggest that forests may partially contribute to decreased SMR of some cancers in Japan.

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Section 6. Research into Forests and Human Health- Recent Trends Worldwide

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Chapter 18

An Introduction to the Forest Therapy Society of Japan, Forest Therapy® and Forest Therapist®

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Background

In recent years, despite the forest being widely recognized in terms of absorption of carbon dioxide and atmospheric carbon fixation, the future of many forests remains uncertain. The advancement of urbanization and the focus on modernization in today's society have often cast forest environments as an obstacle in the path of land development. In addition, as the specialization of industry, spurred by the growth of international economic activity has progressed and forests have gained commercial value for lumber production, a clear division between countries importing and exporting lumber and those who care for the environment has emerged.

More recently, there have been periodic calls for the expansion of forests in order to prevent global warming and halt the man-made spread of CO_2 into the atmosphere, and also for society to produce and release minimal amounts of carbon. The current wave of international efforts to shift from oil to renewable sources of energy has seen large scale attempts to spread these initiatives centralized largely in the Middle East, with the establishment there of facilities that employ cutting-edge technologies, such as solar and wind power generation. Today, all the world's forests combined are capable of removing no more than 20% of the greenhouse gases released by man (IPCC), and with a possible rise in large-scale deforestation to make space for newly established solar and wind power generation facilities, there are mounting concerns that the world's forests will shrink even further.

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The Benefits of Forests

However, as you are probably well aware, the power of forests to maintain and preserve our world's environments is not limited to carbon absorption and fixation. Leaves also capture and retain heat when they come into contact with light from the sun through the process of transpiration, and rather than causing a cooling effect in the surrounding atmosphere, sunlight that filters through the trees to the forest floor has the effect of preserving warm air temperatures within the forest at night and in colder regions. In addition, rainfall and winds can have a calming and regulating effect on the general climate.

Other environmental preservation abilities of the forests are known to include the absorption and adsorption of microscopic aerosol particles (NOx, SOx) that come in to contact with leaves, the purification of pollutants in the air, and the ability to capture water through leaves. Furthermore, the pH balance of the water held within trees allows electrolytes to be taken from the soil and to be purified by the effects of denitrification, which in turn produces high quality freshwater that is essential for all plant and animal life, including human beings, and provides plants and animals with habitats and nourishment.

Forests also offer numerous benefits to human society, including the prevention of sediment disasters by stopping the flooding of rivers and streams, and the provision of lumber as building material for homes, furniture and other items right down to the buttons for our clothing. Forests really seem to be biological resources that may be used for any purpose.

Advanced countries now often use some of these same resources as natural ingredients in foods and commercial products, while native peoples may use them as medicines and, of course, everyone can appreciate the simple beauty of the forest. There are countless possibilities and endless abilities contained within our forests.

Forests in Japan

In the early and mid 1970s, while being aware of some the environmental effects described above, Japan suffered from commercial pressure to export low cost timber. Even so, a long cultural history of treasuring forests saw some Japanese people stalwartly try everything they could protect the forests that had been cared for by their ancestors and that were said to be the dwellings of the gods.

While having a large population, Japan is a relatively small country, comprising only 0.28% of the world's land mass with a national territory of approximately 378,000 square kilometers. However, it is also a long, thin country, stretching from the tropics to the frigid zone: from a latitude of 45 degrees, 31 minutes, 35 seconds north, 141 degrees, 55 minutes, 09 seconds east to a longitude of 20 degrees, 25 minutes, 31 seconds north, 136 degrees 04 minutes 11 seconds east.

Topographically, it houses a rich natural environment with a vast diversity of flora and fauna. This is especially true of its forests, which comprise 66.4% of the country (Forest Area Ref: The Forestry Agency Data), and consist of both tropical and Arctic forests that harbor all species of evergreen broadleaf trees, deciduous broadleaf trees and conifers.

Today in Japan, while issues such as the environment, an aging society and the revitalization of regional economies are pressing, it appears that a partial solution to these three problems, through commercializing the beneficial effects forests can have on people, may finally have arrived.

Due to the importing of low-cost foreign lumber and a sharp decrease in the demand for domestic lumber, and together with the view that the national forests were seen to be falling apart, in 1982, then the Secretary of the Forest Agency, Tomohide Akiyama, coined the term 'forest bathing trip'. Thus, the term "Shinrin-yoku" (Forest Bathing) was created. The definition of Forest Bathing at that time was "absorbing the forests' atmosphere and feeling its power through our five senses" and atmosphere bathing was believed to have healing effects. Therefore (it was not surprising) when the forest atmosphere and its chemical constituents were analyzed by scientists, results showed the existence of sterilizing substances, anti-inflammatory substances and other substances that were expected to have healing effects on the human body. Based on a 1930 research paper ' Plant Bacteriocidein (Phytoncide)' by the Soviet scientist Tokin, Akiyama hypothesized that 'bathing' in a Phytoncide-rich environment would promote better health, and so he encouraged local people to maintain the forests and to endeavor to make a livelihood without needing to cut down trees for lumber. However, at this time, there was no real explanation for the beneficial health effects on human beings, and certainly no hard proof or evidence to back up the claims being made, so the Health and Welfare Ministry (now the Ministry of Health, Labor, and Welfare) assumed the claims were scientifically groundless. However the rumor spread that 'going to the forest may be good for your health'. According to public opinion polls on Forest Activities conducted by the Cabinet Office, the number of people saying that they would like to visit a forest for its beneficial effects was measured at 12.2% in 1992, 15.5% in 1999, and 26.4% in 2003. Yet, regardless of this gradual increase in the awareness of forest activities and the stated desire for forest trips, actual trips to forests for rest and relaxation were an insignificant part of local economic activity. Worse still, more and more forests were being replaced with housing developments. In the latter half of the 1990s, the fresh water-holding capacity of forests was highlighted but with the forests simply being referred to as 'tree dams'. Over the last 20 years, there have been sporadic attempts by multiple organizations to maintain Japanese forests but most of those have not been long lasting.

The Forestry Agency

During this time in 2001, the Forestry Agency initiated its campaign to promote greater understanding of the medical care, treatments and preventative medical potential offered by forests. It also sought to provide medical and scientific explanations for the health benefits seen while relaxing in forests that included a measurable decrease in the stress-related hormone, cortisol. Research in this area has yielded consistent results, providing valid explanations for the claimed health effects and thus led to the establishment of 'The 3 forest-project plans for an aging society' as follows:

1. Forests for medical care and welfare. For general care and nursing to help fight disease or lessen the effects of aging;
2. Forests for treatment and recuperation. For necessary treatment and assisting patient recuperation during convalescence;

3. Forests for lifestyle-related disease prevention. For promoting good health by preventing lifestyle-related illnesses

Forest Therapy Research Group®

In 2004, based on the work of these early researchers, aided by the development of new forms of medical testing equipment and a budget of "Upgrade Agriculture, Forestry and Fisheries research projects utilizing cutting edge technology" was funded by the Ministry of Agriculture, Forestry and Fisheries, and scientists began a study to provide an ‘Explanation of the physiological effects forest environments can have on human beings’. In the same year, government, academia, and private corporate sponsors all collaborated to establish the ‘Forest Therapy Research Group®’. This research group was formed to help develop health products based on the proven results of experiments then being conducted by researchers. In addition it aimed to formally approve and then certify great regional forests as part of the Therapy Road® project. Qualifying forests would be experimentally verified as generating marked physiological, psychological, and chemical differences in test subjects, who walked, sat and gazed in the forests under observation, compared with a city environment base-line.

An area can be designated as a Forest Therapy Base if people involved in the local service industry (lodgings, restaurants, hot springs and other services) along the Therapy Road areas understand the health benefits of Forest Bathing (prevention of disease, lifestyle illness, and psychiatric conditions) and if they co-operate with the research group. Business generated in this way has been helping to stimulate regional economies. The research group successfully held a number of symposiums including a ‘Research Group Establishment Symposium’ and every other month it held other education and training seminars. Other symposiums held by the research group include the ‘Forest Therapy Symposium’, the ‘Forest Medicine Proposal Suggestion Symposium’, the ‘Forest Medicine Kick-off Activities Symposium’ and the ‘International Symposium’. A nationwide ‘Forest Therapy Summit’ was also organized. In addition to certifying suitable forest locations and authorizing selected forest products, the group was also responsible for the publication titled ‘Forest Medicine’.

The Forest Therapy Society of Japan

In 2007, the Forest Therapy Research Group® was dissolved and the Forest Therapy Society of Japan (http://www.fo-society.jp) as an NPO (a specific Nonprofit Organization) was established in its place on March 25, 2008.

The activities of the Society include:

1. The holding of research meetings, training workshops, international conferences and other meetings on forest medicine research (Forest Medicine Study group).
2. The invitation of candidates for Forest Therapy Base and Forest Therapy Road and the authorization of qualifications (Base Credentials Study group). The determination of appropriate physiological, psychological and chemical measurements needed to identify appropriate Base and Road sites, consisting of 8 measurements of the

physiological and psychological criteria of both in the town and in the forest, as well as 5 measurements of the physical and chemical suitability of the forest environment, will be assigned to outside expert researchers, and each result will be entrusted to the judgment of an outside expert committee, the Credentials Committee of Base and Road, and then approved by the Executive Board, with the results announced by the Administration Office.

3. The preparation for organization of a National Network Conference of existing Bases (including Roads), and the running of that conference (Administration Office) While taking into account the unique characteristics of each Base, the Administration Office will also give advice to each Base to ensure the nationwide quality of all facilities, equipment and staff is maintained.
4. The organization of examinations awarding Forest Therapy Guide and Forest Therapist qualifications (Forest Therapist Credentials Study group).
5. The training of personnel (Personnel Training Study group).
6. The dissemination of information and control of public relations regarding Forest Therapy (Dissemination and Public Relation of Forest Therapy Study group). In addition to the publication of HP, guidebooks and journals, this group will work with each local Base to liaise with researchers, inspectors and other visitors including those conducting tests on Roads, and help to provide information to inspectors and other visitors including those from overseas.
7. The control of all clerical and administrative functions and other miscellaneous work. The Forest Therapy Society (NPO) nominally took over all activities of the Research Group, but undertakings related to forest medicine research were largely delegated to the Japanese Society of Forest Medicine (established in 2007 as part of the Japan Society of Hygiene). The Forest Medicine Study Group has been left as a separate legal entity.
8. The Forest Medicine Study Group. The Forest Medicine Study Group, in addition to formally recognizing Bases and their associated Roads, functions as the administrative office for meetings of the nationwide network of locations. In order to assist in the training of those who require knowledge of the Roads in order to become Forest Therapists or Forest Therapy Guides, the Group has even published textbooks in its own right, such as 'Forest Therapy/Forest Therapist Training and Examination Text' and the 'Forest Therapy Examination Supplementary Reader, Field Guide, and Health Care Guide'. As well as conducting examinations, in order to increase national awareness of forest therapy and also as a guide for the general public, the Group has also published 'Forest Medicine II' and the 'Forest Therapy Guidebook'. The Forest Therapy Society of Japan was founded with the aim of examining forest scientific research more closely and sharing all findings with the wider community. As a result of our work the following terms were created:

1) Shinrin Therapy (Forest Therapy),
2) Shinrin Therapist (Forest Therapist),
3) Shinrin Therapy Base (Forest Therapy Base) and Therapy Roads (Forest Therapy Roads).

Three of these terms, Shinrin Therapy, Shinrin Therapist and Therapy Roads, are registered trademarks. These three terms have been registered as trademarks in order to differentiate them from other similar terms that have not yet been scientifically verified using forest medical treatment.

Forest Therapy®

Forest Therapy ® is defined as a program under which "forest bathing" is conducted within specifically chosen forests throughout the country in order to maintain overall body vitality, brain function and general mental health, as well as to prevent disease. The chosen forests should meet the following three conditions: (1) the forest must have a well-maintained forest environment that allows safe and secure activities, (2) the forest environment must be excellent in all physical and chemical aspects, (3) the forest must have a proven environment where certain levels of quantified reaction criteria to particular exertions, that research has shown are among the physiological reactions that work to benefit the maintenance of human life and health, are exceeded. To be more specific, our present objectives are to reduce stress and to improve the immune system. For that purpose, we first conduct physical and chemical experiments on the designated forest environment, and we also test the physiological and psychological reactions of the subjects. We are then able to certify the effects that this forest environment can provide, have reached certain levels.

To practice Forest Therapy®, subjects should do all they can to keep themselves within the designated forest area and with the guidance of a Forest Therapist, they should utilize the terrain by walking through it, sitting to gaze at the scenery and exercising within it, thereby making full use of all five senses. Subjects should also eat well- balanced forest therapy food (in the form of prepared lunches or lunch boxes etc) that uses local organic ingredients. Where possible, as an additional practice, subjects can utilize available hot springs within their surroundings. It should be noted that blood pressure and stress hormone level measurements are taken for city dwellers, both before they enter the forest and again after they complete the Therapy Road activities. Forest therapy is the practice of healthy recreational activities within a forest environment, under the supervision of a medical healthcare system, with the expectation of general medical benefits including identifiable relaxation effects. However until further clinical evidence has been obtained, we must remain cautious regarding specific health claims for Forest Therapy ®. In the future Forest Therapy ® may become a significant medical treatment, but at present it should only be practiced under the direction of a physician.

Forest Therapist®

As a rule, benefits of Forest Therapy® can be obtained by users who go to a certified Forest Therapy Base and walk along a Therapy Road® route. However, we believe it is very important that when traveling a Therapy Road® route that users are accompanied by someone who knows the area well and from whom they can obtain advice on appropriate walking speeds, on what actions should be done in which place to fully engage all five senses and on how their time should be divided between walking and sitting or lying on their backs looking at the trees. If users were to be unnecessarily fixated on the weather, or perhaps become overly concerned about the next stage in the process, they could unwittingly increase their stress levels.

We therefore need people who can act as guides and give appropriate advice. The Forest Therapy Association selects and certifies people who know the local forest area well and who can give visitors guidance on effective forest therapy. Selection is by means of a qualification examination system, and successful persons are assigned to each Base and to each Road. Persons who undergo further training may also be designated as Forest Therapists. Forest Therapists are trained in the following manner.

1) National Standard Qualifications:

Those who are able to secure a certain level of knowledge in general theory will qualify. Two different qualifications are available: Forest Therapy Guide and Forest Therapist.

(1) Forest Therapy Guide Qualification:

Successful candidates are required to understand the environmental science of the forest and the scientifically-proven physiological effects of ‘forest bathing’, and to understand how forest users need to behave in order to receive these benefits. In order to become qualified, candidates must pass a Therapist examination test at one of five nationwide test centers. Qualified persons may then give advice to users on the basic practices of forest therapy and implement these practices.

Users of a Forest Therapy Guide’s services would be those who wish to improve their quality of life by learning exercises and patterns of behavior appropriate for their age, or those who wish to combine the effects of forest therapy with the other forms of health resort tourism already available to them.

(2) Forest Therapist Qualification:

In addition to passing the Forest Therapy Guide examination (see (1)-above) Forest Therapist candidates must also pass a further national standard examination (of the same standard as that for nurses) which includes tests of psychological knowledge appropriate to maintain and improve health and which also tests the social skills necessary to communicate with and properly assist users.

Users of a Forest Therapist’s services would be those who wish to add forest effects to existing medical treatments, or those who wish to improve their quality of life by alleviating mental and physical disorders and chronic diseases, lessening the effects of aging or easing other injuries.

However, no direct medical treatments are allowed by either Forest Guides or Forest Therapists without the guidance of a physician.

2) Local Area Qualifications:

Those who have obtained national standard Forest Therapist ® qualifications are also required to have a certified knowledge of all the Therapy Roads and Forest Therapy Bases in their local area. Each local area will determine the criteria by which these qualifications are awarded. Successful persons will join their local Forest Therapist Society and receive all training necessary for work.

As of 2010, there are 840 Forest Therapists in total nationwide, out of which 520 are Forest Therapy Guides and 320 are Therapists.

Purposes of the Therapy Bases and Roads

The four essential purposes of Therapy Bases and their constituent Roads are as follows:

1) to assist patrons in maintaining and improving their health with the guidance from a trained therapist, as well as to prevent the development of lifestyle-related illnesses, psychological conditions, and other ailments by taking advantages of the proven benefits of 'forest bathing'.
2) to help alleviate the existing illnesses and disorders of patrons through the process of walking the Roads accompanied by a trained therapist, under the overall guidance of their physicians and based on relevant medical and physical examinations, together with appropriate 'forest therapy health checks ' performed on the Roads or in nearby medical facilities.
3) to promote the revitalization of regional economies, through the increased usage of local lodging, dining, shopping and hot spring facilities, as well as other activities of forest therapy participants.
4) to ensure the continued preservation of both natural and planted forest environments in the areas where forest Roads are situated and to ensure the forests maintain their official status as suitable for Forest Therapy use.

We are currently actively pursuing the practical application of all of the above points. Even so, it is vitally important that we strive to continue and extend our research in order to build a society that recognizes the benefits of 'forestification' and that allows people to benefit from the scientifically verified effects produced by the forest environment, while at the same time sharing and promoting these benefits to the world through the implementation of our ideals.

As of 2010, there are 42 Forest Therapy Bases with Therapy Roads and 5 stand alone Therapy Roads in Japan.

We invite candidates to join our organization and hold orientation sessions every year. We have 3 to 5 candidate areas per year.

Recently Japanese researchers have become more interested in how forest bathing might affect a person psychologically rather than the direct effects it may have on the human body. In their research they have successfully identified the following healing effects.

Forest Bathing has been verified scientifically to:

1. Decrease the levels of stress hormones in blood, saliva and urine.
2. Reduce the sympathetic nervous activity and increase the parasympathetic nervous activity.
3. Lower blood pressure and pulse rate.
4. Be psychologically relaxing and reduce tension.
5. Increase the number of natural killer cells.
6. Enhance natural killer activity.
7. Increase the anti-cancer proteins in natural killer cells.
8. Boost human immune function.

The evidence mentioned above was obtained by the following organizations:

1. Forestry and Forest Products Research Institute, Tsukuba, Japan
2. Center for Environment, Health and Field Sciences, Chiba University, Chiba, Japan
3. Department of Hygiene and Public Health, Nippon Medical School, Tokyo, Japan
4. The Japanese Society of Forest Medicine, Tokyo, Japan

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Chapter 19

Forests and Human Health—Recent Trends in Japan

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Abstract

In modern urbanized societies, humans are exposed to too much artificial stimulation, which has negative effects on human health. With increasing interests in health and nature, recent attention has focused on the health benefits of forests. However, little scientific data has been available on the health benefits of forests. Recent evidence-based studies in Japan may provide valuable scientific data and methodology to explore the health benefits of forest environments. Therefore, in this chapter, we outlined the recent trends in research and attempts to utilize the health benefits of forests in Japan. On research trends, a part of our recent indoor and outdoor studies were briefly introduced. Both indoor and outdoor studies provide important data for examining not only the effects forest environments on human body, but also the mechanism by which contact with forests generates the health-related effects. And then we illustrated recent development and systematization of the forest therapy project and the forest therapy station plan in Japan.

Keywords: health benefits of forests, evidenced-based research, physiological response, forest therapy, forest therapy station

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Introduction

Global climate changes and the accompanying drastic loss of biodiversity have been recognized not only as environmental problems but also as critical threats to the health and survival of the human race. Increasing interest in these issues has resulted in the re-evaluation of the importance of forests in recent years.

According to E. O. Wilson’s Biophilia hypothesis (Wilson, 1984), humans have an innate desire to focus on other life forms. This means that humans have a fundamental tendency to maintain contact with nature, and it implies that contact with nature may benefit human health (Frumkin, 2001). Human beings have evolved in natural environments for five million years and have spent more than 99.99% of their evolutionary history in natural environments (Miyazaki et al., 2011). From the perspective that the human body has become adapted to nature for a long time over the course of biological evolution, the current urban environment is an evolutionarily new and unfamiliar habitat (McMichael, 2001). Thus, recent physical and mental health problems may have some causal link with humans becoming isolated from nature. This idea is supported by scientific studies examining the relationship between human health and the natural environment. Ulrich (1984) compared two hospital patient groups exposed either to natural scenes or building walls, and reported that patients who watched natural scenes recovered faster than the other group in the postoperative process. In addition, several demographic studies have shown that greenery in living areas has positive effects on the perceived general health of residents (Maas et al., 2006), longevity of senior citizens (Takano et al., 2002), and socioeconomic health inequality (Mitchell and Popham, 2008).

The physical environment can be a major contributor to individual and community health (Giles-Corti and Donovan, 2002). In particular, nature has often featured as a key component in health promotion models and concepts (St Leger, 2003). In modern urbanized societies, humans are exposed to too much artificial stimulation, which has negative effects on human health.

Furthermore, the rapid development of information technology has brought conveniences in modern life, but has also led to unexpected side effects such as technostress (Brod, 1984). Given this background, recent attention has focused on the health benefits of forest environments. Various products from forests can benefit health. For instance, phytoncides, which are volatile organic compounds released from vegetation, have positive effects on autonomic nervous activity (Kawakami et al., 2004). Contact with wood materials also has favorable psychological and physiological effects on humans (Sakuragawa et al., 2008). Many forest products are used as food, drugs, and medicines.

In addition, forest landscapes and the entire forest environment itself can have a favorable effect on human health. New approaches have been attempted to clarify the health benefits of forests and to apply them to a clinical setting. Recent studies conducted in Japan provide valuable scientific data on the health benefits of the forest environment by quantifying physiological functions such as the activities of the autonomic nerve and immune systems using biological markers (Tsunetsugu et al., 2010). In many Western societies, projects to facilitate physical exercise through contact with nature have been launched to help mitigate health problems.

The natural environment is also being used to ameliorate psychological disorders such as attention deficit hyperactivity disorder (Kuo and Taylor, 2004). Today, there is growing interest in nature-guided therapy.

In this respect, recent evidence-based studies in Japan may provide valuable scientific data and methodology to explore the health benefits of forest environments (Lee et al., 2009; Li et al., 2006, 2007, 2008a, 2008b; Park et al., 2007, 2008; Tsunetsugu et al., 2007). These studies may also have implications in determining how to utilize forest environments in the future to improve human health. As industrialization and urbanization progressed during the 20th century, human lifestyles became more convenient. But despite this convenience, various health problems have accompanied this change in lifestyles, and a common perception exists that many health problems are closely associated with this loss of contact with nature.

Some health projects have been initiated to encourage people to come in contact with forest environments in some developed countries. While a great volume of research has reported the mental and physical benefits of contact with nature, not much is known about the positive health benefits of forests.

More scientific evidence and systemic rigorous research on the physiological health benefits of forest environments are particularly required. In fact, little is known about how forests should be managed to maximize health benefits (Karjalainen et al., 2010). In this chapter, we outline the recent trends in research and attempts to utilize the health benefits of forests in Japan, and we introduce the forest therapy station plan.

Figure 1. Indoor experiment investigating physiological responses when viewing a forest scene.

Research Trends on Health Benefits of Forests

Indoor Experiments

Indoor studies provide important data for examining not only the effects of each forest-related environmental factor on human physiological and psychological responses, but also the mechanism by which contact with forests generates these relaxation effects. In indoor experiments, a single-stimulation study can be conducted with different stimuli and relaxation effects induced by each stimulus can be examined. Another advantage of an indoor study is the ability to take detailed measurements for determining the physiological mechanism leading to a relaxed state.

We have measured the physiological responses of young males when viewing certain forest scenes. Many forest-related visual stimulations caused physiological relaxation, such as subdued activity of the cerebral prefrontal cortex and autonomic nervous system (Figure 1). However, an exceptional response to these stimulations was also observed. When viewing cherry trees (Japanese name: Sakura) in full bloom, elevated activity of the cerebral prefrontal cortex and increased heart rates were observed, which may be related with the deep link between Japanese people and Sakura, causing excitement. (unpublished data)

In another experiment investigating the effects of listening to forest sounds, these sounds reduced both brain activity in the prefrontal cortex and sympathetic nervous activities (Figure 2). This result indicates that forest sounds can promote physiological relaxation. In this experiment, several different types of forest sounds, ranging from the noise of a forest stream to the singing of nightingales and cuckoos (taped earlier in a real forest) were used to monitor the physiological responses of the participants. (Lee et al., 2010)

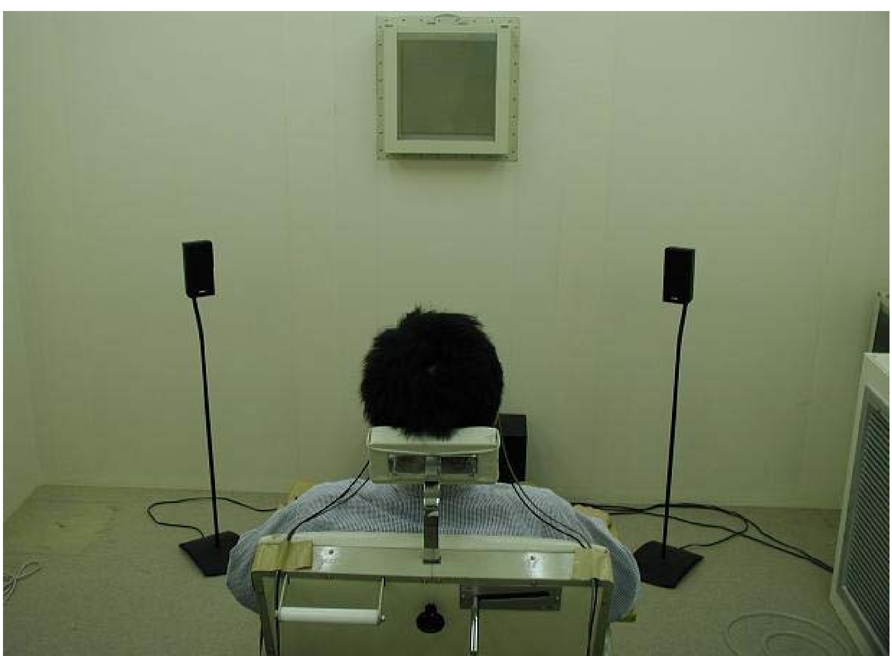

Figure 2. Indoor experiment investigating physiological responses when listening to forest sounds.

Phytoncide, a volatile organic compound released from plants, is considered one of the most important factors in association with the health benefits of forests (Li et al., 2006; Li et al., 2009). Thus, we investigated the composition of phytoncide in real forest atmospheres in more than 30 different forests throughout Japan. More than 100 different types of phytoncide were observed in the forest atmosphere, and in many cases, α-pinene and limonene were the major components of phytoncide emitted in forests. To clarify the physiological effects of relaxation induced by phytoncides, we conducted a 90-s inhalation study using α-pinene and limonene in an indoor artificial climate room. In this study using low concentrations of phytoncides, statistically significant reductions were detected in systolic blood pressure after inhaling α-pinene and limonene. In addition, similar results were obtained in another study using the fragrances of *Cryptomeria japonica* wood chips. Moreover, brain activity was significantly subdued, and subjective assessments indicating a natural and comfortable feeling were evaluated. Detailed data on the indoor experiment is provided in CHAPTER 14 written by Tsunetsugu et al. in this book.

Outdoor Experiments

The investigation of the human response in real field sites is extremely valuable because it can reveal the total effects of the forest environment. A field study provides a more important indication than an indoor study regarding the effects of real environments. A recent field study investigating changes in immune functions with a short-term forest stay provides interesting findings (Li et al., 2007; Li et al., 2008a; Li et al., 2008b).

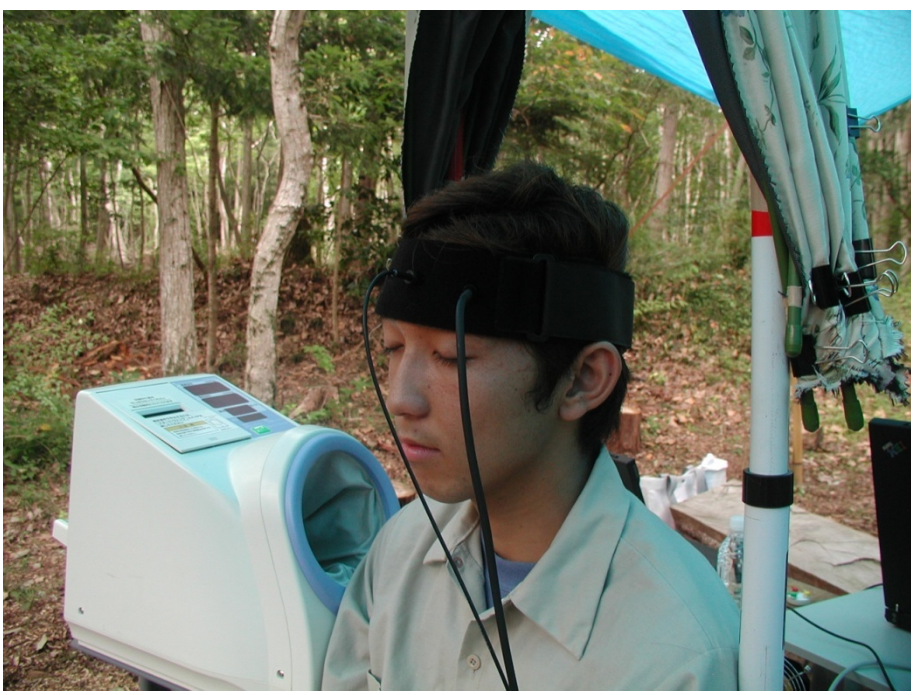

Figure 3. A scene measuring brain activity at a forest field site by time-resolved spectroscopy.

Figure 4. Scenes of field experiments measuring blood pressure (top) and sampling saliva for assessing cortisol levels (bottom).

In a collaborative study with Nippon Medical School, immune functions of middle-aged employees working for major corporations in Tokyo were amazingly enhanced by forest stays. In that study, natural killer (NK) cell activity was measured as an indicator of immune function (particularly as an indicator of anti-cancer activity). Significantly increased immune function was maintained for one month, even after the volunteers returned to urban life, which clearly illustrates the effect of the forest experience from the perspective of preventive medicine.

Measuring the activity of the central nervous system at field sites can be a useful indication for clarifying the relaxation effects of forest environments. We used a time-resolved, near-infrared spectrometer to investigate the activities of the prefrontal region of the brain when experiencing the Seiwa Residents Forest in Chiba Prefecture, Japan (Figure 3). At the same time, the level of salivary cortisol, a kind of stress hormone, was measured. The values of these two physiological markers in the forest significantly decreased when the subjects were walking or sitting in the forest compared with the urban control group, indicating that mental stress can be more easily reduced and that our brain seems to be more relaxed in forests than in urban settings. This kind of human response can be observed more objectively by physiological measurements than by self-evaluation methods such as those employing questionnaires.

In addition, we also investigated the activities of the autonomic nervous system and endocrine system by measuring heart rate variability (sympathetic and parasympathetic nervous activities), blood pressure, heart rate, salivary cortisol levels, and salivary amylase activity (Figure 4). Cortisol levels, sympathetic nervous activity, blood pressure, and heart rate increase and parasympathetic nervous activity decreases in individuals exposed to stress. More than 30 different field studies indicated that compared with urban environments, forest environments enhance parasympathetic nervous activity, which elevates when relaxed, and suppress sympathetic nervous activity, which elevates in response to stress. In addition, the stress hormone level, pulse rate, and blood pressure were significantly reduced in forest environments compared with urban environments, supporting the assertion that forest environments promote physiological relaxation. Concrete data on the responses of the autonomic nervous system in forest fields is provided in Chapter 5 written by Park et al. in this book.

Development of Forest Therapy

Concept of Forest Therapy

Humans have spent most of their time evolving in the natural environment. We now live in urbanized modern societies, but our bodies are originally adapted to natural environments (Miyazaki et al., 2011). With this shift in habitation from natural to urban environments, our body may subconsciously feel uncomfortable and stressful. As expressed by terms such as "technostress," artificial stimulation is likely to have negative effects on human physiological functions.

As a result, stress levels may become too high and our sympathetic nervous system may become overstimulated. Therefore, bringing such elevated stress levels down to normal levels is important for the proper functioning of our physiological activities. This is exactly where "forest therapy" comes into picture. As our bodies get closer to the "expected" state of our natural well-being in forests, our physiological functions including those of the immune system are enhanced and our body functions become more favorable condition. Unlike the expected results when we treat ourselves with antibiotics on contracting a disease such as pneumonia, we do not expect forest therapy to produce such a "specific effect," thereby curing the disease. Instead, we expect a "nonspecific effect" whereby our bodies become more disease-resistant as a result of increased immune function induced by physiological relaxation and normal functioning of the human body.

Scientific Evidence of Forest Therapy

People often feel comfortable and relaxed after coming in contact with forests, and this comfort is gleaned from environmental stimulation through the five senses. Many studies have tried to explore the relaxation effect of nature including forests; most of these studies employed psychological methods such as questionnaires and subjective evaluations. However, expressing these feelings of comfort in words and logically explaining the process of this comfort is difficult because this effect is gleaned from intuitive and illogical processes. Therefore, physiological indicators play an important role in explaining this process of comfort (Lee et al., 2011). Fortunately, with the recent development of techniques for physiological measurement and assessment, changes in physiological activity when in contact with forests can be quantitatively investigated. Scientific data on physiological responses have now been slowly accumulated by a Japanese research group. In recent years, research in this field has shifted from an empirical approach to an evidence-based approach that is based on scientifically quantified data. To detect changes in physiological responses to forest-related stimulations, we measured multiple physiological indices mediated by the activities of the central nervous system, autonomic nervous system, endocrine system, and immune system. We often used salivary cortisol levels, salivary amylase activities, and sympathetic and parasympathetic nervous activities monitored by the heart rate, heart rate variability, and blood pressure as physiological indices because they can be easily measured and are highly valid for observing responses of the body in the field, and their sampling process is noninvasive (Lee et al., 2009). Since 2005, our research group has conducted more than 35 field studies throughout Japan (from the southern edge of Okinawa to the northern edge of Hokkaido). (Lee et al., 2009; Lee et al., 2011; Park et al., 2007; Park et al., 2008; Park et al., 2009; Tsunetsugu et al., 2007; Yamaguchi et al., 2006; Figure 5).

Figure 5. Field experiments for evaluating the physiological effects of the forest.

In studies involving 420 volunteers at 35 different sites, the group of volunteers looking at forest surroundings while sitting down showed the following decreases in endpoints compared with the urban control group: a 12.4% decrease in the cortisol level, 7.0% decrease in sympathetic nervous activity, 1.4% decrease in systolic blood pressure, and 5.8% decrease in the heart rate. In addition, parasympathetic nervous activity was enhanced by 55.0%, indicating a relaxed biological system. This data proves that stress can be relieved after coming in contact with forests. More concrete scientific data on this result are provided in Chapter 5 by Park et al.

We also investigated the response of brain activity in the prefrontal cortex area to forest environments by near-infrared spectroscopy, and found that brain activity decreased in forests (Park et al., 2007). To examine the effects of forests on immune function, collaborative studies were conducted with medical research groups led by Qing Li (Li et al., 2007; Li et al., 2008a; Li et al., 2008b). This research revealed that human immune function increased because of the short-term forest experience, a conclusion supported by increased activities of NK cells and anti-cancer proteins. Detailed information on this research is provided in Chapter 6 written by Li and Kawada in this book.

Shift from Shinrin-Yoku to Forest Therapy

The term *forest therapy* was developed from a Japanese word *shinrin-yoku* (taking in the forest atmosphere or forest bathing). The term *shinrin-yoku* was proposed by Mr. Akiyama (former head of the Japan Forestry Agency) in 1982. Initial attention was mainly paid to plant-derived substances called phytoncides, and usage of the term *shinrin-yoku* rapidly spread throughout Japan. However, at that time, no scientific data existed on the effects of *shinrin-yoku*. The main reason for lack of substantial data was the absence of a methodology for evaluating physiological effects at real forest fields.

In 1990, a Japanese research group led by Yoshifumi Miyazaki collaborated with NHK, a Japanese national broadcasting corporation, to conduct a *shinrin-yoku* study in Yakushima Island, and revealed the relationship between the physiological effects of relaxation and decreased stress hormone levels in saliva. During that study, no established methodology existed for assessing physiological responses to forests, and this attempt can be regarded as a pilot study in our research on forest therapy.

Since then, the physiological methodology for assessing relaxation effects has advanced over the past six years. During 2005–2008, the forest therapy team was formed in Japan with the collaboration of Chiba University and the Forestry and Forest Products Research Institute. Till date, many attempts have been made to establish a concrete methodology. Many physiological indices have been tested, and the validity of each index in field research has been evaluated through collaboration with several research groups and companies that provide facilities for measuring human physiological activities. With the accumulation of scientific data in recent years, new societal and scientific needs to study the health-related effects of forest have arised. With this background, forest therapy research has been developed in an evidence-based manner and has pioneered a new field in science through international research collaboration.

Forest Therapy Station in Japan

Certificate System for Forest Therapy Stations

The plan to set up a forest therapy station began in 2005 with the main purpose of utilizing forests to promote human health. During 2005–2008, more than 35 sites were designated as approved stations (Figure 6). The forest therapy station is approved on the basis of a certificate system. Local governments, including prefectures, cities, towns, villages, and corporations, can apply for this system.

The certification is officially provided after review of the validity determined on the basis of the following three main criteria: (1) the validity of physiological effects of relaxation, which is determined by scientific methods; (2) excellent utilization facility including accommodations and intangible programs; and (3) good forest environments and relating facilities.

Other goals of this certification system are focused on creating economic benefits for local governments, and the restoration of forest landscapes that have been drastically degraded in previous decades. The present plan aims to set up 100 forest therapy stations in Japan within the next 10 years. This plan (from the perspective of preventive medicine) is expected to help solve the problem of excessive national health care expenditure by providing urban residents living in stressful societies with an opportunity to relax. Furthermore, this plan may be a good example of coping with the current major issues of national health problems and the economic degradation problem in local societies.

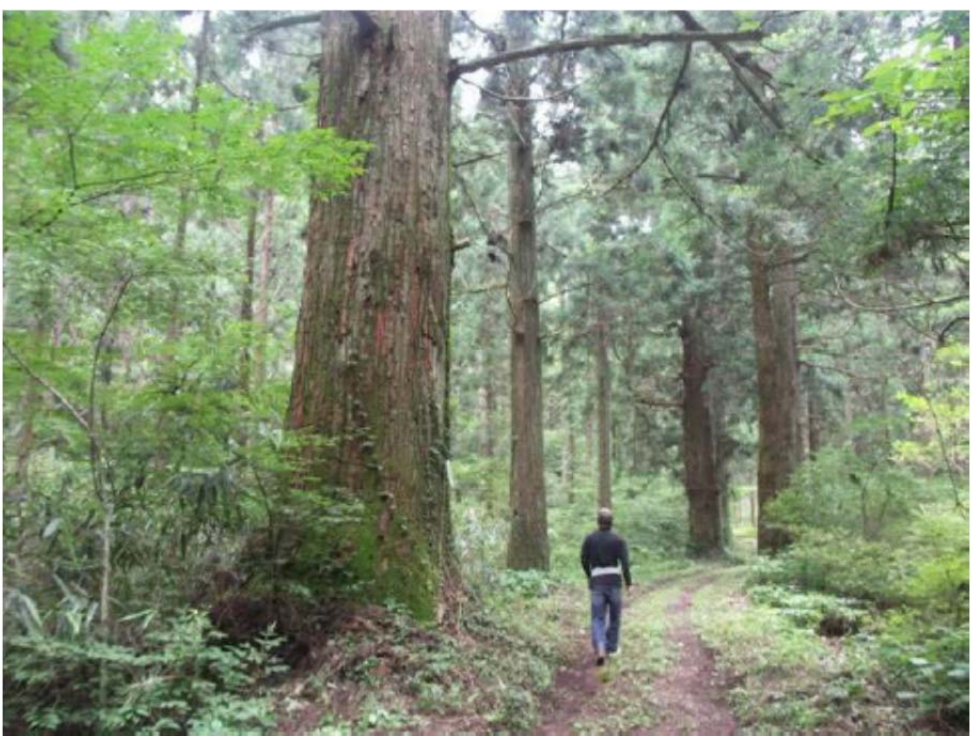

Figure 6. A forest therapy station at Takano Town, Wakayama Prefecture, Japan.

Criteria for Forest Therapy Stations

Among the three criteria for the certification of forest therapy stations, the most important criterion is the results of physiological evaluation. The physiological effects of walking in a forest or watching a forest landscape are assessed by comparing them with those of being in urban areas. The parameters measured include the salivary cortisol level, amylase activity, heart rate variability (sympathetic and parasympathetic nervous activities), blood pressure, and the pulse rate. The validity of relaxation effects is confirmed on detecting two or more statistically significant endpoints. The second criterion is related to the following intangible items: (1) attractive lodging plans, along with any local hot springs, food, history and culture in the area near the site being used for forest therapy; (2) a detailed future plan that includes the prospects for development; and (3) a management system for the project and the approval of community residents. Finally, the third criterion is evaluated in the viewpoint of the fulfillment of tangible items such as (1) a good forest environment and (2) accomodation facilities and hospitals.

Certification of forest therapy stations is provided in accordance with the abovementioned three criteria. Each station has its own unique forest environment, conducts related programs, and provides facilities utilizing the characteristics of each local community.

Okutama Forest Therapy Station

Okutama Town was officially designated as a forest therapy station in April 2008. Located 90 min by train from Shinjuku, one of the urban cores in Tokyo Metropolitan City, the town is known for having the largest number of giant trees in Japan; approximately 1000 giant trees were confirmed by a nationwide forest survey conducted by the Japanese Ministry of the Environment. In 2010, the forest therapy station has now become effectively operational, and the number of users has steadily increased. Serving the Tokyo metropolitan area, its facilities contribute to revitalize the people of Okutama Town and help these Tokyoites relieve stress.

Between May and December 2010, the count of total users rose to 557 participants (Data from Okutama Town) and various events including daily tours and overnight trips to the therapy station were held. The Welfare Department of the Education Bureau of the Tokyo Metropolitan Government has also started using the forest therapy station facilities for government staff. The facilities around Lake Okutama help government employees relax and relieve stress. In addition to five trekking routes through the woods around the lake, the station provides users with various unique programs and activities such as bathing in natural hot springs, noodle making, pottery, stargazing, waterfall viewing, and yoga (Figure 7). In addition, professional health consultations and medical checkup programs are available.

Future Plan of Forest Therapy Stations

The main goals of the forest therapy stations are as follows: (1) economic development of local societies in prefectures, cities, towns, villages, and corporations; (2) revival of degraded forests in Japan, starting with community forests; and (3) reduction in national health care expenditures by reducing chronic stress conditions with the forest experience. We believe that these three goals will definitely be accomplished when the number of approved forest therapy stations reaches 100. Physiological studies have already been conducted in nearly 50 different forests, including 38 different candidate sites throughout Japan. In these studies, important trends in human physiological responses to forest have been observed using some methodologies, and additional data will be accumulated, providing scientific evidence in this research field.

Global Trends on Forest and Human Health Issue

With an increase in the awareness regarding the therapeutic effects of forests, many international research organizations have launched projects to examine the relationship between nature and human health.

Many European countries including the United Kingdom have focused on the health benefits of forest environments. The European Commission-funded Co-Operation in the Field of Science and Technical Research (COST) Action program, which is an intergovernmental network for coordination at the European level of research, was initiated by COST Action E39 in 2004.

Figure 7. Unique programs at the Okutama forest therapy station. Noodle making (top left), crafting (top right), stargazing (bottom left), and yoga (bottom right). Photos by Okutama Town, Tokyo.

Figure 8. The task Force of the International Union of Forest Research Organizations (IUFRO) on Forests and Human Health at XXIII IUFRO WORLD CONGRESS in Seoul, Korea, 2010.

It focuses on forestry and human health and well-being, and aims to increase the body of scientific evidence on the contribution of forests, trees, and natural spaces to human health and well-being. In August 2007, the International Union of Forest Research Organizations, which is the largest global collaboration on forest research, started a task force called "Forest and Human Health." The main aims of the new task force are elucidating various health-related effects of the forest environment, collecting data on initiatives taken by each country, and suggesting potential challenges to be faced in relation to the issues of forests and human health (Figure 8). In addition, Co-Operation on Health and Biodiversity, an international initiative on human health and biodiversity, is attempting to establish a new model in order to link biodiversity and human health and to suggest specific policies related to this problem. Many international organizations or organizations conducting research programs including projects of the United Nations are attempting to solve the issues of nature and human health.

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Chapter 20

Forests and Human Health - Recent Trends in Korea

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Abstract

The purpose of this study is to examine the empirical evidence and describe theoretical perspective that address under what condition and why forest environment can contribute to psychological health and well-being. The review of the literature provides empirical evidence that forest can contribute emotional and cognitive health through forest activity program, social and physical conditions of forest environment, and therapeutic elements from forest. After examining this empirical evidence, the article addresses outline the status, challenges, and opportunities for therapeutic effects of forest in Korea.

Keywords: forest benefits, forest experience, psychological outcomes, therapeutic values of forest

Introduction

The world has become an urban society with a vast number of people becoming alienated from the traditional people-nature relationship. To combat this problem, many urbanites have sought out forest, to search for a different perspective from city life. Forest experience is considered a way to promote balance and harmony in modern urbanites' life. Forest environment has been described as "a great health machine" (Ewert, 1986), and forest

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activities were cited as providing both preventive and forest activity were cited as providing both preventive and therapeutic health benefits (Kaplan, 1995). Extensive research provides empirical evidence that use of forest or viewing forest scenes contributes to reducing stress, promoting more positive moods and feelings, and may facilitate recovery from illness (Ulrich , 1984; Cimprich, 1993; Shin, 1993; Shin, 1996; Shin and Kim, 2007; Shin and Oh, 2007)

The therapeutic effects of forest can be considered as a health treatment in a forest environment. It is possible that forest may provide opportunities which foster the establishment of more efficient and active behavior, thereby enhancing mental, physical health and psychological functioning. Most of the previous studies appraised the values of the forest-related clinical programs in improving the effective performance of delinquents; or in- and out-patients of psychiatric institutions, including emotionally disturbed children; or alcohol abusers; and of people with other clinical mental-health problems.

Therapeutic effects of forests are an emerging social demand in Korea with the trend of Life of Health and Sustainability (LOHAS). To combat this social demand, Korea Forest Service has launched Forest for Human Health project since 2007 (e.g., development of a model forest for human health). What therapeutic effects occur to an individual during his or her experience of forest, and how might these effects enrich an individual healthy? However, empirical attempts to answer these or similar questions have not available in Korea. The purpose of this paper is to outline the status, challenges, and opportunities for therapeutic effects of forest in Korea.

Forest Use and Human Health Benefits

By analyzing empirical studies on forest use, Driver et al. (1990) and Ewert (1986) organized forest benefits into several categories. These include psychological, social, educational, physical and intrinsic benefits. The taxonomy of wildness benefits, according to Driver et al. (1990), takes a broad view, while Ewert (1986) focuses more narrowly on personal benefits of forest adventure recreation. Ewert's use of the words "potential benefits" is similar to the words of "probable benefits" used by Driver et al. (1990). Studies by Ewert and Driver et al. are recognized as the first comprehensive up to gate literature review, including reviews of structured and non-structured forest programs. Although their studies present well-classified categories of forest benefits through the previous literature reviews, they tend not to provide detailed information on each study, such as the purpose of the study, the population and location of the study, the methodology and assessment instruments used, and the overview of the results and comments on weakness and strengths.

The conclusions reached by Ewert (1986) are essentially the same as those reached by Driver et al. (1990), even though they used different terms. Their conclusions were that: (ⅰ) tremendous untapped opportunities for benefits are likely to exist, and (ⅱ) users' willingness to pay (intention to pay more) for forest preservation attest to the sizable benefits which users believe they derive from the experience. This is not surprising since in many of the studies reviewed by the researchers the same conclusions were made. Ewert and Driver et al.'s studies suggest further research, identifying limitations to the benefits research carried out thus far. These limitations include: (ⅰ) as yet unidentified benefits of forest, (ⅱ) it is often impossible to discern whether benefits reported or inferred were uniquely attributable to forest (Scherl, 1998).

The therapeutic benefits of forest can be considered as a health treatment in a forest environment. It is possible that forest may provide opportunities which foster the establishment of more efficient and active behavior, thereby enhancing mental health and psychological functioning. Many empirical studies (Hartig, 1993; Herzog, 2002; Shin, 2007) have examined the therapeutic values of forest. Most of the studies appraised the values of the forest-related clinical programs in improving the effective performance of delinquents; of in- and out- patients of psychiatric institutions, including emotionally disturbed children; of drug abusers; and of people with other clinical mental-health problems.

What beneficial psychological gains occur to an individual during his or her experience of forest, and how might this interaction with forest benefit the shaping of a developing personality? Does an individual's experience of forest offer an enriched perspective on life? These and similar questions have recently intrigued many researchers.

Empirical studies concerning the psychological effects of forest cover a variety of uses, subject populations, and outcome criteria. The studies in which perceived changes in psychological well-being of forest users have been identified, consist of two categories: studies on participants in sponsored forest challenge or survival programs, and studies on general forest users. The results from the previous reconfirm that changes do occur in personal psychological well-being as a result of forest experience. However, most such studies do not reveal anything about how and why the changes occurred. Just how and why does the forest experience result in various positive personal changes?

In addition, most research has not investigated the individual-forest relationship itself. Perhaps, paradoxically, in some of these studies, there has been little suggestion that it is the forest itself that is the essential catalyst for psychological well-being. Of course, there must be some outcome from the relationship between man and forest, but the issue is much more than merely whether forest has provided positive benefits or negative benefits. Instead, Driver et al. (1990) pose questions such as: What are the specific dimensions or nature of forest-related benefits?; Of what extent and magnitude are those benefits?; Of what relative importance are they?; Why should we care about these issues?

How Forest Use Influence on Human Health Benefits

How, then, does the forest experience shape and develop psychological well-being? As Peterson (1997) and Scherl (1988) stated, there have been very few attempts to explain "how" and "why" forest experience promotes psychological well-being. Gibson (1979) also concluded from his comprehensive literature review on forest therapy that there was not generally accepted theoretical formulation for how forest programs bring positive changes in participants' psychological and social functions. Kaplan (1984) and Scott (1974) have pointed out that there has been more research on user characteristics, environmental perception, and types of use, than on the psychological well-being of forest or what aspects of the forest environment contribute to the purported psychological well-being.

Previous studies (Lucas, 1989; Roggenbuck and Watson, 1989; Stankey and Lucas, 1989) have presented evidence that there is a great diversity in users' use patterns, activities, management preferences, and perceptions toward forest. A basic question, thus, is how this diversity affects users' experience of forest and the resultant psychological outcomes. There has been no attempt to relate this diversity to self-actualization, although previous studies do confirm that there are some relationships between self-actualization and forest use. For example, differences in the users' attitude to forest may influence differentially the users' psychological outcome from a forest experience. The experiencing of various environmental conditions is conceptualized not as a static event but as dynamic interaction, mediated by differences in psychological make-up and in how information processed (Tart, 1975; Ittelson, 1978). Based on this conceptualization, it is possible that different forest settings may provide very different specific psychological outcomes. Information on such questions would be very useful to managers as basis for inventory, planning, and management of different forest environments, as, for example, management of an old growth forest, versus management of a forest seashore or a high alpine meadow. In the discussion which follows, the focus is on the theoretical frameworks which may provide guidance to a better understanding of the psychological process which underlie the transactions between an individual and a forest setting.

Research Trends on Forest Therapy in Korea

Even though the use of forest for health purpose has long history in Korea, scientific research on the forest and human health has been performed in recent years. In the 1990’s, several studies on relationship between forest use and health benefits such as stress reduction, hypertension and depression improvements performed. The results of those studies indicated that forest use played significant roles in positive changes in physiological and psychological human conditions. Those studies were considered as initial empirical studies in the field of forest therapy in Korea.

To combat with social demand on therapeutic use of forest, researchers in forestry and medical sciences recognized research need ‘what’ kinds of human health benefits from forest uses and, if any, ‘why and how?’ the benefits come from? Therefore, researchers in forestry and medical sciences formed “Korea Forest Therapy Forum” in 2005. The Forum has been playing an important and central role in research on forest use and human health in Korea. In the academia, the Graduate School at the Chungbuk National University in Korea inaugurated a pioneer Department of Forest Therapy in 2011. The department offers master and doctoral degrees in forest therapy.

Since the early 2000’s, several researchers published books titled “Therapeutic Forest” (Shin, 2005), “Health Travel to Forests” (Shin, 2007), “Green Shower for Health in Forests” (Park, 2006), and papers/technical reports dealing with health benefits of forests. One of the most significant events in the forest and human health area in Korea was the establishment of an interdisciplinary research group in 2005 named “Forest and Health Forum.” The main objective of the Forum is to research evidence-based health benefits of forest and provide the results to the public. To date, there are 200 researchers in forestry, medical sciences, sports sciences, etc involved in the Forum.

Empirical studies on ‘forest experience and psychological health’ also have been conducted actively. Since 1990’s, using various samples of people, many studies have been published in forestry journals. These are: ‘forest campers and their self-actualization increase (Shin, 1993)’, ‘forest experience and alcoholics’ depression (Shin and Kim, 2007)’, ‘forest program and college students’ depression (Shin and Oh, 1996)’, ‘campers in a national park and their place bonding (Shin and Kim, 2007)’, ‘forest view from window and office workers’ job satisfaction (Shin, 2007)’, and ‘urban forest user and their psycho-social outcomes (Shin et al., 2005)’. Most of the studies reported the people who participated in forest program or experienced with forest environment gained positive changes in their psychological well-being.

According to the previous literature review, there are very few studies dealing with subjects who participated in non-structured forest programs. It is also important to note that no studies investigated the benefits related to off-site users or vicarious users. While some of the empirical studies were of questionable validity due to methodological shortcomings, such as a small sample size, it is clear that forest can indeed provide opportunities for positive changes in the psychological outcomes. As several researchers (Ewert, 1986; Driver et al., 1990) have claimed, "we have discovered a black box; we know something works but we don't know why or how" (Ewert, 1986). With further research, forest as a unique natural setting in modern society would be better understood and better appreciated.

Legal Issue and Policy on Forest Therapy in Korea

Social demand on forest use and human health also made introduction of legislation in Korea. In the early 2010, the Korean National Assembly made amendment of the “Law on Forest Culture and Recreation”. In the amendment, the law introduces the definition of forest for human health (or therapeutic forest) saying “Forest for human health is a forest environment designated for improvement human immune system and human health using various forest attributes such as aroma, landscape, etc.” The law also introduces legal process of designation for forest for human health, and related facilities in the forest for the purpose of human health improvement.

The Korea Forest Service also has been designating national forests for human health since 2008, and giving aid to local government for preparing forest for human health since 2009. To date, four national and four public forests for human health are operating in Korea. However, no private forest for human health existing.

Growing Importance of Forest Therapeutic Benefits in Korea

Like many modern societies, Korean society has urbanized rapidly during the last three decades. According to current statistics, more than 87% of the Korean population resides in urban environments. As society becomes urbanized, forest becomes an important resource for the millions of urbanites seeking a quality life. Forests provide opportunities for active outdoor recreation as well as for quiet relaxation and escape from daily urban stress (Shin et al., 2005).

Although evidence-based research has been conducted in recent years, Korea has a long history of forest use for human health purposes. Korea has about 65 percent forest land, therefore, people use the forest to promote and maintain their health. Obtaining herbal medicine, exercise, meditation, green forest shower, and so on are the traditional health related activities in forest in Korea. A recent study of national outdoor recreation survey indicated that more than 80 percent of forest recreationists in Korea mentioned "promote and maintain health" were the main motivation for why they were in forests (Shin, 2007). Natural-being and well-being with nature are emerging issues in Korea. To combat increasing demand of forest use for human health, research in forestry has recently become a major issue.

Conclusion

The results reported in this article offer considerable support on the importance of forest in psychological well-being. Briefly, the results of this literature review have demonstrated that forest environments not only are more desirable than urban scenes (Kaplan, 2001) but also can enhance stress recovery and restoration in a way in which urban scenes cannot (Kuo et al., 1998; Kuo and Sullivan, 2001; Korpela et al., 2001).

Forest environments are not the only kind of restorative environment, but they seem to have numerous advantages over many other settings. There is substantial support for forest settings being preferred as well as restorative (Hartig et al., 1996; Kaplan, 2001). Furthermore, it seems that even a very short opportunity to experience a forest setting can serve a restorative function (Hartig, 1993; Herzog et al., 2002). Thus, a forest experience provides a restorative experience, one that provides a brief respite to one's fatigue and stress.

The use of forests is becoming more complex, the outcomes are becoming more significant to people, especially to urbanites. Psychological health benefits from forest use and experience are important issues in Korea because considering the fact that the psychological stains in daily life are particularly serious under economic and cultural changes. Korea has undergone a enormous financial crisis over the past 10 years, furthermore, its cultural patterns are being rapidly westernized.

It is clear from the literature review that research on forest experience and psychological health benefits is at an early stage of development in Korea, and in global as well. There can be little question that the priority and resources accorded to forest in the future will be largely shaped by the extent to which sound research demonstrates that forest improve health outcome.

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Chapter 21

Forests and Human Health - Recent Trends in China

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Abstract

With advancement of industrialization and urbanization in China, eco-health problems are getting more urgent. Eco-health involves the interactive process of human and environment, thus, research about eco-health is quite complicated, diversified and difficult. Consequently, common efforts by multi-disciplinary and industry sectors are critically necessary. Being the most important ecosystem on earth, forests have great actual and potential value in promoting human health and welfare. However, Chinese researchers haven't yet conducted systematic and thorough studies of the physiological and psychological effects of forest environment on humans. Based on the summarization of current situations in research of this area in China, this paper has analyzed the prospects of research orientations and the methodologies of the forest environment's health effects on human.

Keywords: Forest environment, physiological and psychological effects, current situations, prospects.

Introduction

At present, scholars in China mainly take human's physiological and psychological eco-health; substance and energy metabolism process health of different types of production and life activities; and regional natural and humanity ecological service function health as research areas [1]. The public health benefits of the forest in regard to recreation and health

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cares (FRHCs) may have a strong appeal to the public [2]. Forests lure visitors for sightseeing, vacationing and recuperating in its splendid landscapes and predominant environments. The exploitation and utilization of forest health care tourism resources have been a hot spot in tourism development [3], and forest health care tourism becomes one of important development strategies in forest tourism [4]. Up to now, researchers in China have mainly conducted studies from 5 aspects in the area of physiological and psychological effects of the forest environment.

Spatio-Temporal Changes of Negatively-Charged Air Anion Concentrations and Its Physiological and Psychological Effects

Chinese researchers have conducted relatively systematic studies on the spatio-temporal changes of negatively-charged air anion concentrations in different settings of forest recreation areas, urban gardens and green lands. Wu et al. (2001) selected several typical forest recreation areas in the south of China to study negatively-charged air anion concentrations; the outcomes were as follows: 1) negatively-charged air anion concentrations vary in different forest types; 2) negatively-charged air anion concentrations in forest environment were shown to have a significantly negative correlation to temperature, and positive correlation to relative humidity; 3) negatively-charged air anion concentrations around moving water were higher than that around static water, and negatively-charged air anion concentrations around waterfalls higher than that around streams; 4) there were diurnal and annual variations of negatively-charged air anion concentrations in the forest environment; 5) building materials of recreational facilities such as wooden, stone houses etc., also affected indoor negatively-charged air anion concentrations [5]. Wu et al. (2003) [6] discovered similar conclusions after a study on the air anion concentration surrounding 8 landscape trees, but the diurnal and annual variation of air anion concentrations differed slightly from Wu et al.'s [5]. Wang (2004) studied the effects of urban forests structures on concentrations in Jinlin city, the results were as follows: 1) the air anion concentrations were significantly affected by structures of urban forests; 2) the level of air anion concentrations and air quality grades were highest in multi-stratal forests that comprised arbors, brushes and lawns; 3) while the lowest was on lawns; 4) arbors had dominant effects on the improvement of air quality [7]. A study by Shao et al. (2005) on spatio-temporal changes of negatively-charged air anion concentrations in Beijing showed that 1) negatively-charged air anion concentrations increased but ion polarity ratio ($q=n+/n-$) decreased gradually from city center to suburb; 2) negatively-charged air anion concentrations in forest areas were obviously higher than that in non-forested areas; 3) negatively-charged air anion concentrations in coniferous forests were higher than in broad-leaved forests, and it was the inverse in spring and summer; 4) negatively-charged air anion concentrations obviously increased in the areas where moving water such as waterfalls and rivulets existed; 5) indoor negatively-charged air anion concentrations were lower than outdoor ones but potted green plants could improve it [8]. Cai et al. (2007)'study on air anion concentration at different types of urban green spaces in Yangzhou, Jiangsu Province demonstrated that the air anion concentrations in suburban forests and urban parks were 2 times higher than that at other urban green spaces; the air anion concentration sequence at different green spaces was as follows: park＞campus＞square＞residential district＞center garden of the street [9]. Zhang et al. (2008) researched characteristics of changes of negatively-charged air ion concentration and their relationships with environmental factors in the Mount. Tianmu Nature Reserve; then, diurnal variations (08:00-17:00) and annual variations were tested with a correlation analysis between negatively-charged air ions and 1) particle matter with aerodynamic diameter ＜ 10μm, 2) relative humidity, and 3) air temperature. Results showed that negatively-charged air ion concentration for selected plant communities was in the following order: Cryptomeria fortunei＞Phoebe sheareri＞Ginkgo biloba＞Phyllostachys pubescens. Diurnal variations of negatively-charged air ion concentration were significantly and negatively correlated with PM10 ($r = -0.812$, $P < 0.01$), significantly and positively correlated with relative humidity ($r = 0.820$, $P < 0.01$), and significantly and negatively correlated with air temperature ($r = -0.676$, $P < 0.05$) . Therefore, dynamic water movement, such as waterfalls and streams, could increase the negatively-charged air ion concentrations [10]. Zhang et al. (2006) also summarized air anions' generation mechanism, health and medical effects, assessment methods in tourism environments; and distributing rules of concentration are reviewed [11].

Physiological and Psychological Effects of Plant Essence and Plant Essential Oils

It is different between volatile organic compounds (VOCS) and essential oils extracted from plant organs, which are called as "plant essence", and "plant essential oils" respectively in China. They had been utilized in medical and health care for thousands of years in China; however, it has been just several decades since Chinese scholars conducted research on their functional mechanisms.

Chinese researchers in pharmaceutical industry, forest chemistry industry, food industry and other areas have done a lot of work to study the chemical composition of essential oils, flower essences, as Zhu et al. (1988) published the monograph "Aromatic Plants and its Chemical Composition" [12]. Forest Tourism Research Center in Central South Forestry Scientific and Technical University (CSFSTU) undertook the project "The Plant Essence Research" (1997-2004) sponsored by the Chinese National Forestry Bureau, which investigated the chemical constituents and their ratios of plant essential oils of 156 leafs, 112 lumbers, 20 flowers, 18 forests. As results, 442 chemical constituents were identified, in which 81 monoterpenes,106 sesquiterpenes included [13]. Environmental factors affecting the release of plant essences include physical factors such as temperature, light intensity, water intimidation, relative humility, soil nutrition, CO_2 concentration in the air, and biological factors such as tree age, leaf age, organisms, species, and human disturbance etc. [14-15].

Phytoncides contain a variety of chemical constituents that benefit human health. For example, the essential oils from leaves and wood' of Quercus dentata were mainly constituted by terpenes and its derivatives, including α-pinene, limonene, β-pinene, β-myrcene, 1,8-cineole, camphere, cinnamene, borneol, camphor etc. [16]. Terpenes are regarded to have the foremost medicinal values among the chemical constituents from phytoncides. However, it was reported that VOCS from some living plants like Sorbaria kirilowii might did harm to humans [17]. Nerium indicum Mill released some harmful chemical constituents like acrolein, yet its concentration was so low that it would not be a hazard [18]. Pu and Zheng (2003) found that the fragrances of different plants’ flowers had diverse effects on human bodies’ physiological activities such as negative brain waves (chronic neovascularization, CNV), heart rates, eye pupil variations etc., which could make people excited or equanimous [19].

Plant essential oils were called as “aromatic oils” commercially and “volatile oils” medically [20]. Many plants’ essential oils have fresh and delicious fragrances that could make people equanimous, relaxed or excited [21]. Presently, Chinese scholars mainly concentrated in their research on the extraction process [22-24], chemical composition analysis [25-27], and the insecticidal and bacteria inhibition effects [28-30] of plant essential oils. Extracts of Salvia officinalis leaves were investigated by Qin et al. (2006) for their radical scavenging activities by using four chemiluminescence systems and two colorimetric systems, the results showed that extracts of Salvia officinalis could effectively scavenge $O_{-}2$, ·OH and DPPH, reduce or prevent DNA oxidative damage caused by ·OH and inhibit lipid peroxidation [31]. Some scholars carried out tests on physiological and psychological effects of plant essential oils on rats or humans. Through olfaction inhalation, lavender oil could reduce SD rats′ mean arterial pressure (MAP) [32]. Based on comparing the oral therapeutic index (TI) of plant essential oils and antibiotics, the results showed that the overall effects of essential oils fell short of antibiotics, but they are still helpful in the treatment and adjuvant therapy of skin infections in children [33]. To confirm and study the effects of certain compound essential oil aroma on people’s mental and physical health in yoga practice, a study by Pan et al. (2009) shows that the experimental group compared to the control group, the decrease in somatization, interpersonal sensitivity (P<0.0l), hostility (P<0.05) are ameliorated [34].

Physiological and Psychological Effects of Landscapes Environment

More research on the physiological and psychological effects of landscapes has been carried out in the past 10 years. Teng (2004) designed her research frame based upon the restoration theory of “psycho-evolution” by Ulrich, and “functional evolution” by Kaplan. She utilized and modified the “Landscape Restoration Well-Being Scale” developed by Tseng’s previously. The well-being and restoration surveyed in those five landscape environments were different. People could get higher psychological and cognitive well-being and restoration in the park environment. She found the well-being and restoration provided by on-site landscape experience was much higher than off-site experience; that is, watching the landscape pictures or video. People had diverse recreational motivations in different landscape environment also caused diverse benefits. The well-being and restoration would be achieved by “sight viewing” in the mountain and forest environment; in contrast, by “social motivation” in the park environment. The well-being and restoration of mountain environment were from people's preference for the mountain; the well-being and restoration of forest environment were from people's "being away" of forest. The well-being and restoration of water environment were from people's fascination of water; the well-being and restoration of park environment were from people's intention was compatible with the park [35]. Four graduates in Taiwan University conducted their research on physiological and psychological effects of natural landscapes and environments based on Landscape Psychophysiology and the results were similar to Tseng's findings [36-39]. They used different methodologies that combined noninvasive indexes such as human brain waves and subjective surveys.

In the Mainland of China, some landscape discipline scholars on horticultural therapy carried out tests on physiological and psychological effects of plant landscapes and recreational activities, in which results showed that they would make people equanimous and relaxed [40-44].

Physiological and Psychological Effects of Forest Bathing

In the 80s of last century, Taiwanese scholars Liu (1984), and Lin (1989) systematically introduced the development situations in countries such as Germany, Japan etc. in their works, which promoted the exploitations of Forest Bathing in Taiwan [45-46]. Presently in Taiwan, forest bathing sites are constructed in most forest tourist destinations. In the Mainland, they are also built to meet the more increasing health care needs, such as forest bathing scenic spot in Beijing Red Conch Temple Scenic Areas, Beijing Senxin Forest Park, National Nature Reserves of Zhejiang Tianmu Mount., Fujian Wuyi Mount., and Guangdong Zhaoqing Dinghu Mount. etc. [47].

Some scholars conducted elementary studies on planning and construction of forest bathing sites [47-48], on the use of the training methodology of forest bathing in pre-competition mental state control of male amateur athletes in colleges and universities [49]. Lu (1997) carried out a study on 36 patients with pneumoconiosis by forest bathing rehabilitation and the results showed that patients' headache, dizziness, chest tightness, shortness of breath, cough and other symptoms excluding insomnia were significantly improved [50]. Zhao (2002) pointed out that in clinical convalescence air anion therapy as an adjunct medical treatment was ideal, only when the human bodies lacked vitamin A, E, C, and selenium, the effects were not obvious [51]. Taking military officers as testees, Gan et al. (2005) discussed preliminarily the application of forest bathing in convalescence [52].

Recommendations on Exploitation of Psychologically Health care Forest Tourism Products

Xue and Bao (2010) put forward an innovative design of mental intervention based on forest and leisure tourism products [53], but did not carry out a demonstration study. Chen and Zhong (2010) put forward the mode of forest tourism in regard to psychological health, and the feasibility of improving the technology of psychological health, developing tourism products relating to forest psychology health, etc. [54].

Conclusion

Overseas scholars (mainly Japanese) carried out cross-disciplinary researches on physiological and psychological effects of the forest environment and forest bathing by forestry and health professionals and had made great progress in this field [55-57]. In view of the increasing health care tourism needs of Chinese people, the development of forest health care tourism lagged behind. Lacking of cross-disciplinary studies, the research in this field was not relatively systematic and thorough. This paper pointed out the prospects of this field in China as follows:

(1) Research emphasis. From emphasizing on forest environmental factors themselves to effects of forest environments, and to the systematic study on the spatio-temporal distributions of forest environmental factors and their changes; human physiological and psychological response mechanisms; quantitative evaluations of physiological and psychological effects; study on the optimization and development modes of forest health care tourism products; promoting the in-depth exploitation and utilization of forest environmental resources; and probing health care tourism products; health care service system, health promotion techniques etc. based on forest environment, for example exploitations of forest health care tourism products, such as Chinese traditional medicines, or modern convalescence (SPA, forest therapy) [58].

(2) Research methodology. Enhance the academic research on experience tourism, forest medicine, sanatory rehabilitation science with joint efforts across disciplines, combination of quantitative and qualitative, field and experimental researches. Diversify the evaluation indexes on physiological and psychological effects of forest environment and forest bathing by using fast, efficient and noninvasive indexes like negative brain wave (CNV) etc., and subjective assessment (questionnaires), physiological indexes analysis by collecting blood, saliva and urine. Besides, continually pay close attention to the current development of molecular biology, material science, and instrumentation etc., to introduce new research methods and instruments into this field, such as molecular genetic markers technology.

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Chapter 22

Research into Forests and Human Health- Current Status and Trends in Europe

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Abstract

WHO (1948) defines health as *'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity'*. In this chapter we show that exposure to natural environments contributes to all three dimensions of health. We draw on a study evaluating subjectively determined health and wellbeing. The study supported other research in Europe to show that outdoor activity not only contributes to physical

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and mental fitness but can also help people redevelop a positive self-image that in turn enhances their sense of personal agency and control. We argue for further research so that these benefits can be targeted on those groups who will most benefit.

Global climate change is a threat to the health of people in cities, especially in the Mediterranean region where future summers increasingly will be characterized by extended periods of high temperatures. The risk to health is illustrated by the 2003 heat-wave in Europe that in some cities gave rise to a 40% increase in mortality. In built-up urban environments green spaces have been shown to reduce urban heat-island effects. In addition, green spaces can provide a range of ecosystem services that impact positively on human health and well being.

Providing for disability requires an understanding that there are many types of disability, including hearing, sight, speech and learning impairments as well as physical impairments. Providing equal access to the outdoors requires a sophisticated approach that recognises that people with disabilities have a range of different needs. This section explores issues such as barriers to accessibility, which are not only physical but include a lack of facilities and information. A better understanding of the needs of disabled groups is the starting point for meeting legal requirements for equal access.

Trees generally contain higher concentrations of specific bioactive defense substances than annual plants. Some tree extracts have been known since ancient times for their health-promoting properties, such as terpenoid resins from pine, spruce and mastic trees. Other substances extracted from European trees have been found to exert promising health-promoting effects. Bark and knots are especially rich sources of bioactive polyphenols, in particular of various lignans, stilbenes and flavonoids, which are strong natural antioxidants. Polyphenols extracted from trees are already marketed widely as nutritional supplements and may also be introduced in specialty, functional food products, like the xylitol and sitosterol products that have been marketed world-wide for more than ten years.

Keywords: Forests, Green spaces, Human health, Research trends, Europe

Indroduction - A Historical Perspective on Human Health and Nature

To the majority of human beings in the world today, those who still rely on traditional approaches to health rather than Western medical models (WHO, 2008), the link between nature and health is taken for granted. Not only in the use of medicines derived from their local environment but also as the basis of a general sense of physical and spiritual wellbeing.

The idea that people are part of nature occurs in all the major religions, though perhaps most explicitly in Daoism dating back to 6thc BC that in turn greatly influenced both Confucianism and Buddhism (Miller, 2008). In Western culture the concept survived the enlightenment relatively intact; indeed its adoption by the scientific world was a milestone in the development of modern science. Had Charles Darwin not seen humans as part of the natural world it is difficult to see how he could have applied his theory to human evolution.

Darwin's delayed publication of his *Origin of Species* arose in part from the dilemma he believed would arise in reconciling his theories with the religious beliefs prevalent in society. However, scientific and religious or cultural understandings of the world were able to co-exist and even join together.

In recent modern times examples of popular culture that link wellbeing and happiness to association with nature are commonplace. We can see them, for example, in the late 19th and early 20th centuries in the arts and craft movement, in the images of the Romantic painters and in the outdoor teaching and performance developed in Switzerland by Dr Rollier with his heliotherapy and by Laban in his summer dance school at Ascona. Across Europe sanatoria were built with gardens and farms in recognition that outdoor work and activity was beneficial to mental health. Patrick Taylor (2006, p.226) accounts how in the UK between 1674, with the building of the Bethlehem Asylum in London, and 1914 at least 130 asylums were built that were *'… huge institutions set in extensive grounds, some more than 100 hectares…'* in addition to these mental institutions *'… other types of hospitals developed, all requiring large grounds …'*. These were characterised by opportunities for patients to exercise and to work in the grounds as part of their therapy. Whilst today the sun continues to be seen as a source of health (Schuster, 2010) society's attitudes towards the living world have become more ambivalent and these hospitals have almost without exception closed or have sold off their land. The link between health and nature that was accepted almost without question until the early 20thC today finds little support among the public health and scientific communities.

Simon Schama (1995) reminds us that the relationship between society and nature is *'a current that flows through all the ages of Western culture'*. That is not to say that the nature of the relationship has remained constant. Aristotle himself believed that nature could be explained through the study of physics, that it was governed by laws that could be discovered (Stanford Encyclopaedia of Philosophy, 1999). Scientists since then have sought to do exactly that.

Perhaps the greatest recent change in the relationship has been in our perceptions of human agency. Western society today has a greater confidence in its capacity to take action unconstrained by nature and, indeed, to bend nature to its will. Michel Foucault (1966 cited in Hacking 2005) suggested that the concept of Man as central in the world is a recent, modernist invention that will pass away. Nonetheless Governments and society continue to ascribe to an increasingly anthropocentric and instrumental view of nature. It is reinforced by scientific and technological discourses in which human bodies are seen as machine-like and tempered by official constructions where nature is categorised as a hazard and source of risk. In consequence the personal agency of individuals is constrained and through a process of codification and professionalization it is re-assigned to the domain of particular professional groupings; for example in the areas of climate change, food safety and even health and safety more generally.

Prior to the Second World War in both science and the arts we see an unselfconscious acceptance of the relationship between nature and health. Indeed Morris (2003) recounts that the right to enjoy access to natural spaces for health and recreation was seen as a benefit worth struggling for. Access to the countryside was politically contested, with landowners in the UK resisting attempts by urban people and factory workers to use the countryside for recreation. After the war this link disappears almost completely in both professional and popular writing. One possible cause is that the appropriation of 'nature', or at least of landscape, by the fascist parties. The projection of the countryside as an idealised aspect of national identity introduced a racist dimension that made it an unattractive field for researchers or writers to explore.

Immediately after the war we saw rapid modernisation of agriculture accompanied by the development of new institutions such as the Common Agricultural Policy. Rural and agricultural policies were based largely upon a technological and market-based philosophy that persists to the present day and greatly influences the way that society understands the countryside. In the 1970^s a number of adverse, unforeseen impacts of rapid agricultural industrialisation began to be recognised. This gave momentum to modern environmentalism and to environmental regulation supported by scientific research. Whilst early environmentalists such as Rachel Carson (1962) had an explicitly ethical approach today environmental arguments tend to be couched in terms of scientific evidence and regulatory compliance[1]. Today's countryside is a strongly regulated space and, again, this influences society's understanding of nature. We can, therefore, argue a case for four possible reasons why the natural environment is no longer seen as a resource for health: (1) that an existing, implicit cultural construction of the countryside was made untenable by a nationalistic appropriation of nature, (2) this created a space that was occupied by a rationalist and technological discourse that became embedded by the post-war institutionalisation of the countryside, (3) an increasing sense of human agency in respect of the laws of nature has led to a cultural shift where society sees itself as an external observer rather than internal participant in nature and (4) a secular rationalisation of nature that gives prominence to professional scientific discourses and expresses society's relationship with the natural world through a discourse of risk.

The development of a science-based, medical approach to health is perhaps one of the greatest scientific and humanitarian achievements of the last century. However, its success has squeezed out approaches that are not supported by a particular type of evidence. Traditional approaches and culturally derived concepts of health and healthy behaviour fit uneasily within this dominant paradigm of science and technology. Nevertheless, the idea that exposure to the natural world is important to health continued to find resonance in the personal experiences of scientists and health practitioners as well as the wider public. For example individuals who value subjectively the time and activity they spend in the outdoors or parents who see benefits for their children in outdoor activity and learning. Nilsson et al. (2010) relate how modern lifestyle-related health problems, such as chronic heart disease, obesity, stress and poor mental health have become an increasing concern across the world. Public health is attracting increasing attention and health authorities are looking for fresh approaches that can help them address these contemporary problems. Scientists reflecting on their subjective experience have over the past few years started to apply their professional skills to hypothesise a link between exposure to natural environments and positive benefits for health. They have begun to formulate research questions that not only allow their subjectively determined knowledge to be explored through the disinterested process of scientific research but also present their findings in a way that resonates both with scientific and policy communities in health and environment. Importantly their work is also attracting the attention of resource managers, those who are responsible for managing parks, forests, urban green and blue space and other accessible natural areas.

Europe countries spend between 8% (OECD) and 11% (WHO) of their GDP on health. If positive benefits of exposure to natural places can be demonstrated, and ways can be found of

[1]Contrast the ideology of the 1972 Stockholm World Summit ('… mankind's whole work and dedication must be towards the ideal of a peaceful, habitable and just planet …') with its 1992 successor in Rio.

delivering those benefits to the people in greatest need of them, then even a small overall positive effect will have a large economic value that will very rapidly repay the costs of research. Whilst such research is at an early stage it is already very clear that the potential value of the benefits justifies a much larger research effort. We hope that the quality and rigour of current research will encourage mainstream research funding bodies to dedicate more resources to this field. In this chapter the current status and the trends in research on forests and human health in Europe will briefly be described and discussed.

1. Therapeutic Spaces: Exercise, Mental Health, Illness-Specific Therapy

In parts of the world it is generally accepted within the forest management sector that there are health benefits to be gained from work and recreation in nature and in the forests. It seems somewhat different in the health sector: Tellnes and Furuberg (2010) suggest that there is still a long way to go before the active use of nature, and of culture, is integrated into health strategies at all levels: local, regional, national and international. What can we do to achieve increased awareness and understanding of these benefits among health personnel? We suggest that interdisciplinary collaboration, especially between forest and health professionals, should focus on two priority areas: a) Maximizing the health benefits of forests and b) Manage risks to health that stem from forests. If we accept that the natural environment plays a role in the health and well-being of all living beings then our challenge is to build a research base to understand the links between forest ecosystems and human health and well-being, framing our studies within the concepts of ecological sustainability. The components of a healthy life include mental, physical and social well-being. Reduced mental stress arising through exposure to natural environments, including forests, is thus an important component of human wellbeing. Other health benefits include pharmaceuticals, nutraceuticals, forest food and herbs gathered or derived from forests. Also included here are the positive contributions that forests can make towards cleaner and healthier environments, for example through cooling or interception of particulate and gaseous air pollution. Health risks include vector-borne diseases, where their dispersion can be connected with deforestation and forest ecosystem degradation, as well as hazards linked with forests such as falling branches or irregular terrain. The benefits of physical activity on human health are well documented. However, it is not clear whether the same physical activity, when undertaken in forests and natural settings, has the same or a different effect on human health than when undertaken in an indoor setting. How do the benefits of running in a forest, for example, compare with running on a treadmill in a gym? (Nilsson, Sangster and Gallis, 2005). In the following case study we discuss data related to physical activity undertaken in natural and forest environments.

A Study on Holistic Illness-Therapy and Rehabilitation in Norway

This study explored how a holistic and salutogenic approach might be beneficial in the rehabilitation of people with long-term illnesses. It included specific therapies such as nature-culture-health activities and energy psychology (Batt-Rawden and Tellnes, 2011). Successful rehabilitation programs that promote a positive mental outlook may improve participant's wider wellbeing. Problems within both the working environment and in one's private life can have a cumulative effect and lead to increased illness and sickness absence. Rønning, Solheim and Batt-Rawden (2008) refer to this as the 'total life burden'.

Aims of the present study. The main aims of this study were: a) to evaluate the subjective health and wellbeing of participant's at a rehabilitation center after they had participated for four weeks in a therapeutic programme, b) to understand the mechanisms in play and c) to identify those rehabilitation programmes that delivered the greatest perceived benefits for the participants.

Methods for rehabilitation-specific therapy. During a four week long stay at the rehabilitation centre the participants were offered two sessions of physical activity and nature experiences daily. These were combined with sessions on energy psychology (Gallo 1998) and tutorials on lifestyle changes, both individually and in groups. The specific therapies included walking in the forest, mountains or through cultural landscapes, as well as swimming, gym and dance. Over four weeks the rehabilitation process focused on learning how thoughts, beliefs, actions, relationships, social networks and the natural environment might influence our energy levels, function and capacity for work. The process was grounded in the life experiences and current life situation of the participants. Batt-Rawden and Tellnes (2011) give greater detail of the therapies used.

Methods used in the present evaluation study. The first part of the present study includes 38 participants at a rehabilitation center in Norway over a period of four weeks. Their subjective opinions, beliefs and life experiences were explored using a semi-structured interview guide. Grounded theory was chosen as the qualitative methodological approach, since the research questions attempted to explore and describe social processes of illness and health as they emerged from the ethnographic data. (See Strauss and Corbin (1998) for an account of the techniques and procedures for developing grounded theory)

Results from the rehabilitation process over four weeks. Three main factors seemed to contribute to participants' perceived recovery.

Physical activities and nature experience. Physical activity combined with outdoor experiences such as walking on forest or mountains trails, or sitting calmly and looking at the countryside after a brisk walk, had a substantial positive effect on their subjective sense of well-being. Furthermore, being physically active had a positive effect on self-esteem and self-perceptions such as body image: *"I feel much better when I am physically active every day. It gives me energy and vitality, and I don't get so depressed"* (Photo 1).

The social environment and Sense of Coherence. An important factor that contributes to participants' sense of recovery was how participants' construction of the social environment as a 'significant other'. This supported their sense of coherence and predictability (Eriksson and Lindström, 2008), hence giving the participants vitality and energy through meaningful social interactions. In this respect, difficult or adverse life circumstances and negative emotions may be modified via social strategies and transformed to positive emotions by achieving a readjustment of self over time: *"Being here has made me rethink how I live my life, and how I can change my behavior and live a different life onwards. I will focus on the daily routines I have learned here".*

Learning to adopt a new lifestyle. The increased self-awareness of participants, and their better understanding of the importance of physical activity, contributed to feelings of well-being and vitality. Through learning new techniques and tips the participants' energy is channelled into action and lifestyle changes, maintaining health-performance.

Discussion. An holistic approach to rehabilitation raises questions about the way in which individuals reconstruct their values. Holistic practices have shown positive results in promoting healthy lifestyles. Successful interventions include encouraging physical activity or recreation, providing employment advice and support and promoting greater social inclusion (Batt-Rawden and Tellnes, 2011). The findings in this study supported recent studies that conclude that active participation in cultural activities reduces pain, anxiety, promotes health and increases longevity (Tellnes, 2010; Batt-Rawden and Tellnes, 2005)

A salutogenic perspective: Through daily routines at the rehabilitation centre, where they engaged in different activities, several participants experienced a "greater sense of coherence" (Eriksson and Lindström, 2008). This can have direct physiological and psychological consequences, affecting our health status, particularly in coping with stressors in the rehabilitation process (Griffiths, 2009). Previous studies also show correlations between sense of coherence and mental health and well-being (Langius and Bjorvell, 1993; Erikssson, 2010). This "sense of coherence" seems to strengthen resilience and lead individuals to develop a positive subjective state of health (Batt-Rawden and Tellnes, 2011).

Concluding Remarks

The salutogenic and holistic approach to health and rehabilitation, which included exercise, energy psychology and walking in forests and wider landscapes, improved the mood of participants. Thus experience of nature might help people to reconstruct their values, identify coping mechanisms and revitalize the energetic and resourceful parts of self. Salutogenesis is a valuable, holistic approach for promoting health. It deserves to be used far more than is current practice. (Tellnes, 2010; Batt-Rawden and Tellnes, 2005, Batt-Rawden and Tellnes, 2010). The study support the importance of exposure to natural environments as a means of promoting health, reducing stress, rehabilitation stressed individuals and improving overall wellbeing. These findings are supported by other studies in Europe (Gallis, 2005). Bell et al. (2005) in a study covering Scotland and the East Midlands of England reported that *" Woodlands and nature reserve areas were the types of nature that scored highest for many aspects involved in reducing negative feelings including stress reduction and also for increasing positive aspects such as feeling energetic and finding woods to be magical places".* These findings indicate the potential value of further studies so that we can better understand the optimal use of physical activity in natural settings in order to improve the mental and physical health of people in Europe.

2. Climate Change and the Human Environment: Shade and Cooling

There is a general scientific consensus today that the world's climate is changing as a result of man's activities. A recent IPCC (International Panel on Climate Change) report states that global averaged mean surface temperature has increased by about 0.6 ± 0.2°C since 1861 and is projected to increase by 1.4 to 5.8°C by 2100 (IPCC, 2001).

The European Environment Agency (EEA) predicts that as a consequence of climate change Southern Europe will experience extreme weather events such as increased drought stress, more frequent heat waves and forest wildfires, increased heat stress and risks for human health. A WWF climate scenario for the Mediterranean confirms that summers with extreme heat, that today seem exceptional, might become the norm if we do not manage to keep average global warming below that dangerous threshold of 2°C compared to pre-industrial levels (Giannakopoulos et al., 2005).

Urban environments have particular characteristics. Extensive modifications of the land's surface, buildings, traffic, and heat generated by air-conditioning and other indoor climate control technologies contribute to elevated temperatures in urban areas, a phenomenon commonly referred to as the urban heat island effect (UHIE) (Rosenfeld et al., 1995; Weng and Yang, 2004; Kosatsky, 2005). Many European cities demonstrate significant heat island effects (Santamouris, 2007a) that can raise ambient temperatures by 1° to 10 °C depending on the nature of the heat sources in the area. For example, a time-series of heat island measurements in Athens gives a clear picture of the phenomenon in the city (Mihalakakou et al., 2004). They show that the heat island effect can raise temperatures by close to 10 °C (Mihalakakou et al., 2002) with serious impacts on the wellbeing of residents and also on energy consumption of buildings, which require increased cooling. (Hassid et al., 2000; Santamouris et al., 2001).

The UHIE is likely to be accentuated by climate change and to exacerbate the impacts of heatwaves on cities (IPCC, 2001). Higher temperatures from climate change, combined with the UHIE, have implications for air and water quality that will, in turn, impact upon green space, human comfort and building integrity. Intensification of heat stress episodes is one of the main factors threatening human health and well-being, and limiting the quality of life in many European cities (Nogueira et al., 2005; Poumadère et al., 2005; Nicholls and Alexander, 2007).

Heat stress in people can occur when air temperature, radiation, humidity, and wind create conditions where the auto-regulation of a person's body temperature can fail (Motamedzade and Azari, 2006). Exposure to high temperatures can result in a spectrum of outcomes for people's health and well-being that range from mild discomfort to life-threatening medical conditions (Dessai, 2002; Johnson et al., 2005).

Thermal discomfort is at the mild end of the spectrum and is distinguished from the more severe effects of heat stress by the absence of significant potential for adverse medical outcomes (Michelozzi et al., 2005). However, sign and symptoms of thermal discomfort can include feelings of heat exhaustion, nausea, insomnia, irregular breathing and heartbeat/pulse, worsening of pre-existing illnesses and conditions (Kalkstein and Greene, 1997).

Populations that are vulnerable to the adverse health effects of heat waves are those groups with pre-existing illness, young, elderly, and frail populations (McMichael et al., 1996; Patz and Kahling, 2002; Meusel et al., 2004). A disproportionate amount of heat-related mortality results when heat-stress amplifies cardiovascular, cerebrovascular, and respiratory co-morbidities (Patz and Kahling, 2002).

It is estimated that 22,080 excess deaths occurred in England and Wales, France, Italy and Portugal during and immediately after the heat waves of the summer of 2003. Data for Italy, provided here for the cities of Bologna, Milan, Rome, and Turin, are compatible with the earlier estimate that 3,134 excess deaths occurred in the 21 Italian regional capitals during the period 1 June-15 August (Kovats et al., 2004; Michelozzi et al., 2005).

In response to these events, Ministries of Health and other public health authorities, along with national and international meteorological services and organizations and civil defense authorities have focused attention on the development of strategies and measures to reduce adverse impacts on health arising from extreme weather and climate events (Meusel et al., 2004).

A range of measures can mitigate heat stress in urban environments. They include increased areas of green spaces, e.g. city parks, urban woodlands, street trees, rooftop gardens, and vertical greening on buildings (Li et al., 2005).

Urban forests provide a range of ecosystem services that impact positively on human health. Ecosystem services can be broadly defined as environmental processes that support human health and well-being, either directly or indirectly (Millennium Ecosystem Assessment, 2005; Boyd and Banzhaf, 2007; Elmqvist et al., 2008).

Urban green spaces provide air filtration, noise reduction, rainwater drainage, flood control, sewage treatment, carbon storage and sequestration, mitigating the urban heat island effect, and microclimate regulation (Bolund and Hunhammar, 1999; Jo, 2002; Elmqvist et al., 2008). All these services provided by urban greenery have direct or indirect importance to human health and wellbeing.

Green spaces improve urban microclimate mainly through (1) shading, that reduces the amount of radiant energy absorbed and stored by built surfaces, and (2) evapotranspiration, that evaporates liquid water through the plant leaves, thereby cooling the air (Simpson, 2002). Spronken-Smith et al. (2000) reported that evapotranspiration from parks exceeded water evaporation from surrounding areas by more than 300%, significantly reducing air temperatures in their vicinity. In this way city trees and vegetation can markedly lower summer temperatures in cities (Hough, 1989).

These processes in turn help to create comfortable outdoor settings, reducing the symptoms of thermal discomfort in heat-stress conditions (Nikolopoulou and Steemers, 2003; Shashua-Bar and Hoffman, 2003; Georgi and Dimitriou, 2010).

A further function of trees, particularly in warm regions, is to control luminosity and solar radiation, not only reducing reflection from paved surfaces and the accumulation of heat within the city but also reducing the warming effects as building and hard surfaces release absorbed heat. (Gomez et al., 2004).

These processes in turn help to create comfortable outdoor settings for people and can reduce the symptoms of thermal discomfort under heat stress conditions (Nikolopoulou and Steemers, 2003; Shashua-Bar and Hoffman, 2003). Gomez et al. (2004) analyzed the influence of green areas on the urban comfort of the city of Valencia, taken as typical of Mediterranean cities. They found that vegetation reduces albedo and the amount of solar radiation reaching urban spaces. They developed comfort indices and showed a positive correlation between human comfort and proximity to green zones.

The effectiveness of urban forests and other types of urban vegetation for cooling, and their effect on urban microclimate is well documented (e.g. Santamouris, 2007b, Dimoudi, 1996; Ferrante and Mihalakakou; 2001; Santamouris, 2001; Akbari, 2002; Gomez et al., 2004) (photo 2 and 3). This is not new knowledge. The Arabs adopted the shading effect provided by trees in the design of their gardens. (photo 4).

According to Zoulia et al. (2009) the temperatures between urban green areas and built-up areas can differ by 7°C or more during the summer. Georgi and Dimoutri (2010) showed that a progressive increase in green areas in Chania, Greece, affected the urban landscape and the microclimate positively, providing protection from solar radiation and decreasing the temperature up to 3.1°C.

Correlations between microclimatic parameters like air temperature, relative humidity and solar radiation in the sun and shade of trees in parks during summer have also been investigated (Georgi and Zafiriadis, 2006). In the case of large green spaces such as parks, vegetation lowers the surrounding air temperature and thus improves the thermal environment of the urban area.

Parks and other urban green areas can be several degrees cooler than the surrounding neighborhoods (Dimoudi and Nikolopoulou, 2003; Yu and Hien, 2006; Andrade and Vieira, 2007; Gill et al., 2007). According to Ca et al. (1998) a nearby park can reduce the air temperature by up to 2°C in the surrounding area. In the 8.5 ha urban park Gulbenkian Park in Lisbon the temperatures for a 60 days summer period are on average 1° to 3°C lower than the nearby streets (Andrade and Vieira, 2005).

In higher latitudes the cooling effect of green areas is lower. A study measuring air temperature at ten sites on a transect across a Primrose Hill, a London park, found temperatures to be on average 0.6°C cooler in the park than on neighboring streets over a 12 hour period. The main shopping street, that offered no shading, was up to 3°C warmer than the centre of the park (Graves et al., 2001).

Woody vegetation affects temperature not only in summer but also in winter. In particular, shaded areas suffer less thermal shock. Panagopoulos (2007), studying the effect of olive trees shadow on soil temperature, found that during summer period soil can be 11°C cooler under olive shadow and during winter 4°C warmer. As a result of shading, soil surface temperatures in a park may be 12°C lower than the daytime temperature of a street surface and according to Akbari (2002) urban tree planting can account for a 25% improvement in net cooling and heating energy usage in urban landscapes.

Among other factors, the effect of vegetation on the microclimate depends on the size of the vegetated area. While the cooling effect is limited for a single tree or a small group of street trees (Oke, 1989), larger areas such as parks can have a significant cooling effect (Yu and Hien, 2006). According to Kuttler (1993) a significant climatic effect can only be expected when park size exceeds one hectare, while a size of 10 ha is required to lower air temperatures by 1 °C . The results of a study by Dimoudi and Nikolopoulou (2003) suggest that an average temperature reduction of around 1 °C can be expected for every 100 m^2 of vegetation added to the park. We can see that not only are some exogenous factors (such as the specific measurement techniques used, the weather types and the size of the samples) likely to influence the results, it also seems impossible to establish a linear relationship between the size of the parks and the thermal differentiation associated with them, due to the fact that the latter is highly dependent upon the structure of the vegetation, the topography and the characteristics of the built-up area (Andrade and Vieira, 2007) .

This cooling effect is observed within the area of the park as well as the surrounding area, particularly at the leeward side of the green space (Dimoudi and Nikolopoulou, 2003). The distance over which a park can influence the temperature of the surrounding area has ben investigated in several studies. The range effect was found to depend mainly on the park size and on the distance of the built-up surroundings from the park border. It was shown that the influence of large parks (500 ha) reaches a radius of up to 2 km, about the same as the park dimensions (Jauregui, 1990) while smaller parks (about 35 ha) may influence areas extended at a distance of 1 km, depending on wind conditions (Ca et al., 1998).

Moreover, the higher the ratio of green to built space in an urban area the greater the air temperature reduction is to be expected. In addition, urban spatial characteristics such as the configuration of the buildings and of the open spaces have also been found to be a significant factor influencing outdoor thermal comfort. The urban canopy layer (UCL) significantly influences microclimate, especially urban-rural and intra-urban air temperature differences (e.g. Shashua-Bar et al., 2004; Burbia and Bucheriba, 2010).

Shashua-Bar et al. (2010a) in a recent study in a Mediterranean area, Tel-Aviv in Israel, reported that the potential cooling effect of the trees was found to depend mostly on its canopy coverage level and planting density in the urban street. The characteristics of individual species were relatively unimportant. This is a factor to consider when selecting tree species in urban planning.

With the exception of a significant literature on the role of urban parks, however, little work has been done on microclimate conditions in streets at pedestrian height or under the vegetation canopy in streets with greenery (Shashua-Bar et al., 2010b). Field measurements conducted by Shashua-Bar and Hoffman (2004) showed that some tree-aligned streets and boulevards in the Tel-Aviv area had 1–2.5°C lower air temperatures than non-vegetated streets in the hottest part of the day (15:00 h). The factors and parameters involved in passive cooling of canyon-type streets with trees have been studied by the same authors. Using a model that considers both construction materials and building geometry, they demonstrate that cooling depends on the amount and extent of the partial shaded area (Shashua-Bar and Hoffman, 2003). Another study conducted by Shashua-Bar et al. (2010b) showed a strong relationship, correlation coefficient 0.92, between the estimated trees' cooling effect and the tree canopy ratio in Athens, Greece. The higher the tree canopy ratio, the higher the cooling effect. This relation, however, is not uniform since the effects are partly due to the tree coverage level and partly due to the street's built-up geometry. Their model indicated that the total attenuation effect in reducing the air temperatures inside the streets may reach as much as 5 °C at noontime with a daily average cooling of 3 °C.

Planting trees around buildings, especially on south façades, can reduce warming from solar radiation. This in turn reduces electricity demand for cooling and thus lowers peak power consumption (Santamouris and Asimakopoulos, 1996; Papadakis et al., 2001; Georgi and Dimitriou, 2010). Vegetation alters the energy balance and energy demands for cooling buildings through sheltering windows, walls, and rooftop from strong solar radiation and from radiation reflected from surroundings (Yu and Hien, 2006). Deciduous plants shade the buildings in summer but in winter when their leaves have fallen the plants let solar radiation through to be absorbed by the buildings (Papadakis et al., 2001). Thayer and Maeda (1985) showed that certain deciduous trees can reduce solar radiation rates by 25% to 50%, with an average reduction of 35%. The magnitude of this effect depends on the density of the foliage. More detailed information can be found in Stec (2004), Miller (2007), and Köhler (2008).

Recent investigations have included observations on green roof throughout the year. Teemusk and Mander (2010) observed reduced roof temperatures in summer months for a green roof and grass-sod roof as compared to a steel roof and a SBS (Styrene Butadiene Styrene) modified bitumen roof. Temperatures were also observed during the other seasons. In winter, the temperatures of the substrate layers of the planted roofs were higher than those of the surfaces of the conventional roofs with average amplitudes of 1°C for the planted roofs versus 7–8°C for the conventional roofs (photo 5, 6 and 7).

This is a method of passive temperature control that results reduced air conditioning and a smoother energy load profile (Papadakis et al., 2001; Nguyen, 2005).

Konopacki and Akbari (2002) reported that by mitigating UHIE in Houston it was possible to achieve savings of USD 82 million with a reduction of 730 MW peak power, together with an annual decrease of 170000 tonnes of carbon emission. Rosenfeld et al. (1998) used numerical simulation and predicted an annual reduction of 25 GW of electrical power or potential savings of USD 5 billion for the US by year 2015.

Simpson and McPherson (1996) summarized several modeling studies indicating that shade from a mature tree (about 7.62 m in crown diameter) would reduce annual air-conditioning use by 2– 8% (40–300 kWh) and would reduce peak cooling demand by 2–10% (0.15–0.5 kW) for cities across the United States.

Based in these evidences, a wide scale project was organized, with the aim of examining and evaluating a broad range of comfort condition, e.g. thermal, across Europe. Project RUROS (Rediscovering the Urban Realm and Open Spaces) aimed to improve the urban realm and revitalize city centres by integrating social and environmental objectives. The researchers undertook extensive field surveys to understand and evaluate comfort conditions across Europe. These encompassed climatic variation, urban morphology, cultural background and personal differences between users of open spaces (Nikolopoulou and Lykoudis, 2006).

In the context of the emerging issues related to climate change and heat stress episodes, a collaborative research framework has been established between research groups in Italy and the UK within the British–Italian Partnership Programme 2005–2006: Climate Change: The UK and Italy's role in a global challenge jointly financed and managed by the British Council and the Italian Ministry for Universities and Research. A collaborative research project called INTERFACE (INTEgrative Research on Forest Areas, Citizens and urban Environment) has been carried out with the general goal to contribute to the theoretical and empirical understanding of well-being in relation to urban environments. Specifically, the research aimed at investigating the benefits and well-being generated by urban forests and green spaces on people when heat stress episodes are more likely to occur (i.e., summer periods in the Northern hemisphere). The results suggest the existence of a systematic positive relation between the use of green spaces – expressed in terms of frequency and duration of the visit – and the benefits and well-being reported by individuals at the time of the survey (summer 2006). Factors such as preference for shade and importance of accessibility to water during the visit were also positively related to most of the items measuring benefits and well-being, though with different degree of correlation. Interestingly, ''preference for shade'' appeared more related to the psychological side of the benefits than to the physical side (Lafortezza et al., 2009).

Results also suggest that green spaces offering shaded locations and accessible water could benefit people and, at some extent, alleviate symptoms of thermal discomfort under heat stress conditions (Nikolopoulou and Steemers, 2003).

In the Mediterranean area, the results of a study conducted by Sanesi and Chiarello (2006), regarding public green spaces in the city of Bari - Italy, show that respondents to a telephone survey perceived the green areas as a life-quality enhancer, confirming the findings of previous studies carried out in Italy and in other countries. Citizens are moreover conscious of the limitations in quality and quantity of green areas in their own city, and they see the public and private green areas as single beneficial system. In this geographical context citizens also reported different patterns of behavior in their use of green areas at different times of day. In southern Europe users prefer green areas full of trees where there are many shaded areas. The mid and late afternoon hours are preferred over noon and early afternoon (Lafortezza et al., 2009).

The biophysical features of green space in urban areas, through their cooling and microclimate effects, clearly offer potential to help cities adapt to climate change (Gill et al., 2007). Urban green spaces themselves can help to mitigate climate change by capturing and storing carbon dioxide. This is an important factor to consider with the increased risk of urban heat waves that will most likely occur in the wake of climate change (Frumkin and McMichael, 2008).

According to Mooney et al. (2009), the capacity of ecosystems like urban forests to provide services essential to society and human health and well-being is already under stress, and the situation will worsen under most projected climate change scenarios. As locally generated ecosystem services can have substantial effects on human health and quality of life in urban areas, the use of green spaces in towns not only helps mitigate the effects of climate change but also helps reduce the very substantial environmental footprints of European cities. This is an important consideration for land-use planning (Bolund and Hunhammar, 1999).

Concluding Remarks

Many European countries, particularly in the south of Europe, are particularly vulnerable to climate change and are increasingly affected by extreme heat waves especially during July and August. During this period heat stress can cause premature deaths among citizens.

There is an increasing body of research that illustrates the capacity of green spaces to lower the summer temperatures in urban areas, with potentially very large economic benefits not only for health but also in reduced electricity consumption and lower peak demands that require lower capital investment in generating plant. These studies are empirical and there are many variables to consider. The underlying mechanisms through which vegetation and trees mitigate the hot summer are shading, evapotranspiration and wind-speed reduction.

Natural green environments within towns improve the quality of urban space not only physically but also psychologically. There is increasing evidence that natural spaces induce a an enhanced perception of personal and community well-being. Urban forestry and urban greening is spreading across Europe. The EU itself is funding such programs and the Forestry Action Plan includes a specific chapter on urbanism and suburban Forests.

3. Forests and Disability

According to the European Disability Forum 65 million people within the EU have a disability. This is 10% of the EU population (EDF, undated). This group is diverse; it includes people with hearing, sight, speech and learning impairments as well as those with physical impairments. Finding effective ways to ensure equal access and enjoyment of the outdoors and forests for all of these groups of people is a requirement under much national legislation and arguably under EU disability legislation. In Britain for example, where there are an estimated 10 million disabled people (DWP, 2006), the diversity and equality agenda in Britain is supported by the Equality Act 2010 and the Disability Discrimination Act (DDA) 1995 (Government Equalities Office, 2010; DRC, 2003). In the DDA a disabled person is defined as someone who has a physical or mental impairment that has a substantial and long term adverse effect on his or her ability to carry out normal day to day activities.

Land management organisations such as the Forestry Commission[2] in countries such as Britain are working to meet their legal obligations to identify, consult, and include disabled people in the development of policies and services of importance to them. Answering the challenges of the equality and diversity agenda means learning more about disabled people's expectations, needs and the potential mechanisms for including different users of woods and forests, such as the wide range of disabled groups and the variety of recreational activities they undertake in woodlands.

Disabled Groups and Access to Forests and the Countryside

There is little literature on disabled group's engagement with, use of and views of the countryside or woodlands. Research such as the Diversity Review in England (Countryside Agency, 2005) was set up in 2002 and finished in 2006. It aimed to investigate what could be done to support disabled people, black and minority ethnic people, people living in inner city areas and young people in outdoor recreation participation. Research was undertaken to explore perceptions and reasons for under-representation in countryside use by these groups through surveys and by qualitative methods. Results suggest that disabled people believed they enjoyed physical and psychological health benefits through contact with the natural environment and they enjoyed having new and varied sensory experiences. Problems with accessing the countryside included transport issues, costs of visiting and lack of knowledge of available facilities.

Research was commissioned by Forestry Commission to identify physical, social, cultural and attitudinal barriers (Burns et al., 2008). It was conducted in seven forests in England, Scotland and Wales and included people with physical impairment, learning disability, mental health issues and sensory impairment. The research found that disabled people valued woodlands and wished to have access to them. Disabled people felt that woodlands and the wider countryside were beneficial for health and well-being, social inclusion and identity. These spaces were used to meet others and enjoy company but also sometimes to get away from other people. Those involved in the research suggested that the barriers they experienced in accessing woodlands were not so much related to their physical impairments but to external issues such as the provision of suitable information and appropriate facilities.

A study by Henderson (1995) in the United States of women with physical disability found that the impact of a given disability depended on the nature of the disability, whether the disabled person had taken on board the traditional role expected of a disabled person and the reaction of other non-disabled people. The research found that the disabled women tended

[2]The Forestry Commission is the government department responsible for protection and expansion of Britain's forests and woodlands.

to have less free time, a lack of opportunities and choices and often felt a certain amount of dependency on others as they needed assistance in particular aspects of their lives.

In Denmark many of the state forests have facilities to enable access for mobility impaired people. The Danish Forest and Nature Agency provides details online where people can see what disability facilities are available at that forest sites. In Sweden the ‘Green Staircase’ initiative is targeted at the long term unemployed and those with disabilities. Participants get involved in activities in the forest and are supported in assessing how they can get back into work. The project is based on the idea that working with nature is rehabilitating (Eurofound, 2009).

Barriers to Accessibility for Disabled Groups

A recent synthesis of existing qualitative and quantitative research (Morris et al. 2011) found that the key barriers to accessing woodlands for disabled groups included the following:

- Woods were not always seen as safe
- Lack of facilities such as appropriate information
- Mobility reasons making it difficult to get around on site
- No car to reach a specific site
- Site too far away
- Not enough information available to allow forward planning.

Lack of access to, access on, and information about sites are key barriers for disabled respondents (Burns et al., 2008) who often need to plan visits in advance. Transport issues are also prominent as many disabled people do not have access to a car and find public transport difficult. Stiles, gates, toilets and other forest-based facilities and features can also be unsuitable for wheelchair and scooter users. Cold can also act as a barrier with many disabled feeling the cold more than others. Some respondents voiced concerns about other forest users, for example fear of cyclists whom they might not hear or see very well and who sometimes pass them quickly and too close for comfort. Some respondents talked about feeling awkward because they feel that they are perceived as not belonging in woodlands.

Disabled respondents particularly emphasised the need for much more detailed information about access and facilities, preferably supported with photographs, so that they could choose appropriate woodlands and plan their visit (Burns et al., 2008).

‘What is a waste of time is just going out in the countryside with your scooter and hoping to do a ramble. 90% of the time you won’t be able to. You’ve got to know where to go, and that information, a database of accessible places is hugely needed’. (Disabled person, Burns et al., 2008, p.48)

There are concerns that organisations trying to respond to people with disabilities have to great a focus on physical impairments rather than other types of disability, too strong a focus on people’s condition and not enough on finding out what they want and enabling that to happen (Burns et al., 2008). It is suggested that a culture of fear is being created through constant references to health and safety issues.

Forest Managers Understanding

Research has been undertaken in Scotland to understand forest managers' knowledge and skills related to disability accessibility (Bell et al., 2007). The research found that there was awareness within the forestry sector of the need to promote disabled access however knowledge of the DDA was not high and managers felt the need for advice on a range of issues such as the most useful ways to approach and involve disabled people and organisations that focus on disability. Managers suggested that key obstacles to their carrying out more activity to promote accessibility for disabled groups included finance and the staff resources needed to make changes as well as the potential physical limitations at particular forest sites that might limit what facilities can be provided.

Generally recreation managers were not aware of how important information is to disabled users and how they use this to assess whether they can access a site and what to expect when they reach a forest site. When thinking about and discussing disability forest recreation managers often think about wheelchair users rather than people with other types of disability such as hearing, mental illness or visual impairment (Bell et al., 2007). However, some forest sites are making wider provision such as the Mamhead Sensory Trail at Haldon Forest Park in Devon that provides Braille and tactile maps for those with visual impairment. Some forests also provide all terrain mobility buggies known as 'trampers', these are specifically designed for off road use on beaches and in forests and the countryside. Managers also felt that they needed more training and guidance for how to make spaces more inclusive for the disabled.

Designing Appropriate Spaces for Disabled People

A sensory rich trail design framework was produced for the Victoria Government in Australia, after a twelve month project of research and consultation was undertaken to find out the needs of users and managers (Nillumbik, undated). An important aspect of design is to involve mangers, designers, potential users and other stakeholders in the process so that a greater understanding and awareness is reached of needs and potential opportunities. The framework highlights the need to carry out sensory mapping of a site to assess what it has to offer in terms of touch, sound, sight and smell and then seating, planting and access design can be planned in relation to this. In Britain the Sensory Trust[3] focuses on making places more accessible for everyone regardless of age, disability or background and this includes a focus on design of spaces for different groups of people. In the Trust's 'Making Connections' (Price and Stoneham, 2001) publication they divide disabled groups into the following as a check list for design requirements and design suitability:

- Semi-ambulent (mobility impaired) people
- Wheelchair users
- People with sensory impairment
- People with learning difficulties
- Elderly

[3]An independent charity organisation

They suggest that when designing accessible places consideration needs to be given to on site accessibility, interpretation, and off site access. Community involvement is also important in designing suitable spaces that meet local need.

Concluding Remarks

Research highlights that it is important to understand that disabled groups are not homogenous and there can be significant differences between groups. Obstacles that prevent access need to be addressed; one obstacle can be overcome however two or more obstacles can become too much for disabled people to surmount. Daniels et al. (2005) note the importance that disabled travellers place on the actions and attitude of others. For example, the willingness of staff to push and pull wheelchair users along a forest trail is said by one respondent to have "*made the difference between just 'looking' and actually 'seeing' what was around us.*'' (Daniels et al., 2005, p.925). Better understanding is required of disabled groups needs when accessing woodlands, it is also important to know more about forest managers understanding of disability issues, and how to design spaces suitable for a range of people. Outreach work between forest staff and local disability organisations is one important way of providing new opportunities for disabled people. Providing appropriate training for forestry professionals is important that takes into account specific forest and recreation issues.

4. Medicines from Forest Products

Health-Promoting Products from Trees in Europe

Forests, which once covered most of Europe, provided wood material for buildings and tools, as well as wild game for food and warm fur clothing. Berries, nuts and mushrooms were important food supplements providing certain key vitamins and minerals. Furthermore, certain tree species were important sources for health-promoting products. More recently, modern health-promoting products have been developed from bioactive compounds that can be extracted in large amounts from trees and thus supply industrial-scale world-wide markets. Forest products are already important sources for pharmaceutical manufacturing. A selective review of the current and future trends in research of the medical and pharmaceutical used forest products is introduced in the section.

Pine Resin

Pine resins have been used in traditional medicine since ancient times. Today, they are still used as the basic component of various medicinal preparations, often in ointments containing pine resin and beeswax. However, the pharmaceutical and medicinal properties of pine resin have not yet received extensive attention from the research community.

Medical trials on animals have shown that pine resin (PR) and pine resin ointments (PRO) can be highly effective in the treatment of wounds and burns during phase I of the wound process, in cell regeneration at the wound surface and formation of early granulation tissue (Simbirtsev et al., 2002a). In vitro studies of the antibacterial activities of PR and PRO on wounds and burns (Simbirtsev et al., 2002a) have shown that PR is characterized by pronounced bactericidal effects. The results showed that during the early stage of the inflammatory process, PRO modulated non-specific and inhibited specific immune response, normalized hemodynamics in the inflammation focus, activated regenerative processes in tissue, and was effective against anaerobes and bacilli. The preparation of PRO inhibits humoral, but stimulates cell immunity. In particular, in the therapy of burns PRO stimulates non-specific immune response, normalizes hemodymanics in damaged regions, and stimulates proliferation of epithelial cells (Khmel'nitskii et al., 2002).

In vitro experiments have shown that preparations containing PR activate phagocytosis and hold much promise for the therapy of burns, wounds, purulent andinflammatory diseases (Simbirtsev et al., 2002c). The same experiments showed that PR and PRO contain various bioactive substances producing opposite and dose-dependent effects on phagocytosis (Simbirtsev et al., 2002d).

Rosin, formerly called colophony or Greek pitch (*Pix græca*), is the major product obtained from pine resin. Rosin and rosin derivatives have been pharmaceutically evaluated as microencapsulating materials and as anhydrous binding agents in tablets (Fulzele et al., 2002, 2007; Satturwar et al., 2004; Lee et al., 2005). Rosin biomaterials have excellent biocompatibility and degradation features, and film-forming ability (Fulzele et al., 2003). They show potential as components in film-based drug delivery systems and dosage technology (Satturwar et al., 2005; Fulzele et al., 2007) and relevant research is continuing.

Chios Mastic Gum

Pistacia lentiscus var. Chia of the *Anacardiaceae* family is grown almost exclusively in the southern part of Chios island, a Greek island in the Aegean. Chios mastic gum (CMG) is a white, semitransparent, natural resin that is obtained as a trunk exudate from mastic trees. Mastic gum and essential oils from *P. lenticus* are natural antimicrobial agents used in Greek medicine in classical times by physicians such as Hippocrates, Dioscorides and Galenos, who mentioned their properties and recommended their use for various gastrointestinal disorders like gastralgia, dyspepsia and peptic ulcer. Nowadays, mastic gum is used in surgery for the production of special stitches that are absorbed by the human body. In dentistry it acts as an oral antiseptic and tightens the gums (Topitsoglou- Themeli et al., 1984). The essential oil is used in perfumery and in the cosmetic industry (Doukas, 2003). Medical trials have shown that mastic gum may have cyto-protective or anti-acid effects for the gastrointestinal system, such as relief of ulcers (Al-Habbal et al., 1984) and reduction of the intensity of gastric mucosal damage caused by antiulcer drugs and aspirin, with little or no side effects. It has been reported that mastic gum possesses considerable in vitro antibacterial and antifungal activity (Magiatis et al., 1999; Tassou and Nychas, 1995), for that verbenone, alpha-terpineol, and linalool seem to be responsible (Koutsoudaki et al., 2005). It has been specifically reported to be effective against *Helicobacter pylori* and peptic ulcer (Huwez et al., 1998; Bona et al., 2001; Marone et al., 2001).

Chios mastic gum has also been traditionally regarded as an anti-cancer agent, especially against tumors of the breast, liver, stomach, spleen, and uterus. Recent studies demonstrating that CMG induces apoptosis (Balan et al., 2005) and possesses antiproliferative activity in human colon cancer cells (HCT116) in vitro (Balan et al., 2006). CMG has already been associated with cardiovascular protection. It inhibits human LDL oxidation in vitro (Andrikopoulos et al., 2003) and due to the triterpenes that are major constituents both of the neutral and the acid fractions, it acts on peripheral blood mononuclear cells to elicit an antioxidant and anti-atherogenic effect (Dedoussis et al., 2004). Although CMG's antioxidant effect is widely known, whether it can directly inhibit atherogenesis has not been clarified and further research is needed.

Pine Tar

Tar manufactured by pyrolysis of resin-rich pine trees was the most important trade item from the area that now is Finland from the 16^{th} century to the middle of the 19^{th} century. The tar was used mainly to preserve and protect wooden ships, buildings and tools, but was also used as a health product. There is even a traditional saying in Finland that "if sauna, tar or spirits do not help, the disease is fatal".

In Finnish folk medicine pine tar was used as an antiseptic agent for treatment of ailments in humans and animals. Hair louses were abated by tar. Tar water was used against various contagious diseases. Still today, small amounts of tar are used in soaps and shampoos, and in the treatment of skin diseases, such as psoriasis, eczema and rosacea. Tar is also used in veterinary care products, especially on horse hooves, and on cattle and sheep as a natural antiseptic germicidal treatment (Anon. Pine Tar).

Tar is still produced in small scale in Finland and Sweden especially for use in protection of ancient wood buildings. However, there are currently no serious efforts made to develop modern health-promoting products from tar.

Spruce Resin

Another product with long traditions is spruce bark resin. It was scraped off from the bark of old spruce trees and chewed by rural people in Sweden and Finland since ancient times. It was considered good for the teeth, keeping them clean and providing an antiseptic effect. In America, the first colonists were introduced to spruce chewing gum by the native Indians in the early 1600s (Anon. Chewing gum). Spruce chewing gum was commercially manufactured in the United States and was marketed already in 1848 as the "State of Maine pure spruce gum".

The resin used for chewing was not ordinary wood oleoresin, but so-called callus resin, that is exuded from the callus tissue formed after damage to the bark. The resin is found as nodules or lumps on the rim of the closing wound. The callus resin is chemically completely different from ordinary oleoresin. Pure callus resin from Norway spruce (*Picea abies*), i.e., the resin scraped off in Sweden and Finland for chewing, is composed of lignans, with pinoresinol as the main component, lignan esters with lariciresinol coumarate as the main ester, and free *p*-coumaric acid (Holmbom et al., 2008).

Native Americans mixed white spruce (*Picea glauca*) resin with fat to make salves for treating skin infections, insect bites, chapped hands, cuts, scrapes, burns and rashes (Anon.

Chewing gum). Spruce resin has also been used as a resin salve in northern Sweden and Finland for centuries. A few years ago the spruce resin was rediscovered in Finland and developed by the company Repolar into a modern salve product with the trade name “Abilar” (Sipponen et al., 2007). It has been documented that the resin salve has bacteriostatic effects and is effective against pressure ulcers, burns and wound infections. It has been approved by the National Agency for Medicines in Finland and is since 2008 sold in pharmacies. High amounts of resin acids, as well as lignans are dissolved into water from the resin salve. Recently, a related product named “Abicin” has been introduced, that is stated to be effective against fungal nail and foot infections.

Research on spruce resin for health protection is continuing. Its antimicrobial effects are studied on a variety of bacteria, including multiresistant bacteria such as MRSA and VRE, The mechanisms of action and the role of various components in the resin are also explored. Research is also being made to incorporate softwood resins in other products where antimicrobial properties are important, such as, for example, plastics, fibres, paints and washing agents.

Xylitol for Prevention of Caries and Ear Infections

The sugar alcohol xylitol (Figure 1) can be produced by acid hydrolysis of xylans, the dominating hemicellulose in decidous (hardwood) trees, followed by reduction of the obtained xylose to xylitol. Xylitol was developed to a health product in Finland in the 1970´s. Research at University of Turku documented that xylitol can inhibit tooth decay, caries (Sheinin and Mäkinen, 1975). Production of xylitol was built up in Kotka, Finland by the Finnish Sugar Company. Xylitol-containing chewing gum was developed and marketed as a product promoting dental health. Later, xylitol has been found also to inhibit ear infections in children (Uhari et al., 1996). After approval by US FDA in the 1986, xylitol has spread world-wide, and is now used as a specialty sweetener in large variety of food products.

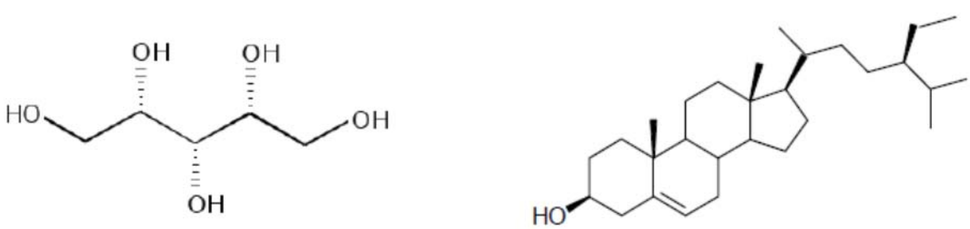

Figure 1. Chemical structures of xylitol and sitosterol.

Sitosterol and Sitostanol for Lowering Blood Cholesterol

Sitosterol (Figure 1), the dominating sterol in plants, including trees, was reported already in the 1950´s to inhibit cholesterol from being absorbed into the blood stream (Miettinen et al. 1995, and references therein). Sitosterol was produced in France from tall oil, a by-product from the pulp industry, already in the early 1970´s. At that time, sitosterol was used mainly in cosmetic products. Sitosterol production from sulfate soap, a by-product from chemical pulping, was developed in Finland in the 1970´s, and a production plant was built at a pulp mill in Lappeenranta. In 1995, the company Raisio in Finland introduced a new margarine product, with the trade name Benecol, containing sitostanol fatty acid esters as the active ingredient. Sitostanol is the saturated analogue to sitosterol and can be produced by catalytic hydrogenation of sitosterol. The Benecol^{TM} margarine marketed as a cholesterol-lowering functional food, attracted large attention all over the world.

Today, there are a large variety of Benecol products: cream cheese, pasta, yoghurts, sour milk, meat products, etc. Several competitors to Benecol have come up, producing similar products based on sitosterol fatty acid esters, or mere sitosterol, using the same cholesterol-lowering arguments in their marketing. The total annual production of sitosterol and sitostanol for use in functional foods now exceeds 10 000 tons, of that about 5 000 tons is extracted from tall oil, a by-product from paper pulp production.

Tannins from Pine Bark

Bark, being the protecting "skin" of trees is also a rich source of bioactive compounds. Bioactive bark products are already on the market. Pycnogenol is the tradename for extract from bark of the maritime pine growing in the region south of Bordeaux in France (Anon. Pycnogenol). It contains a complex mixture of phenolic compounds, mainly so-called procyanidins and bioflavonoids (D´Andrea, 2010). Between 65% and 75% of Pycnogenol are are procyanidins comprising catechin and epicatechin units with varying chain lengths. It is a powerful antioxidant. Pycnogenol is said to be good for cardiovascular health, skincare, diabetes health and inflammations, among others.

Research on Pycnogenol, as well as other tannin-rich bark extracts, continues intensively in many laboratories, regarding both the chemistry and the therapeutic applications of the various components in the extracts.

HMR lignan –a New Anticarcinogen and Antioxidant from Spruce Knots

Lignans are a class of natural polyphenols composed of two phenylpropane units with a bond between the C-atoms in the β-position. Lignans occur in most plants in low concentrations. Certain tree species contain high concentrations of polyphenols, including lignans in their knots, i.e. the roots of branches (Holmbom et al., 2007). Knots of Norway spruce, the dominating spruce in Europe, contain high concentrations of the lignan 7-hydroxymatairesinol (HMR) (Figure 2), on average about 10% of lignans, with HMR comprising 70-85% of the lignans (Willför et al,. 2003). The variation between knots is large; values all from 6 to 29% have been found. Spruce trees in Northern Finland contain considerably larger amounts of lignans than trees in south Finland (Piispanen et al., 2008).

HMR was tested for its biomedical properties in the 1990´s at University of Turku, and significant inhibition of breast cancer growth was documented, first in *in vitro* tests and later in rats (Saarinen et al., 2000).

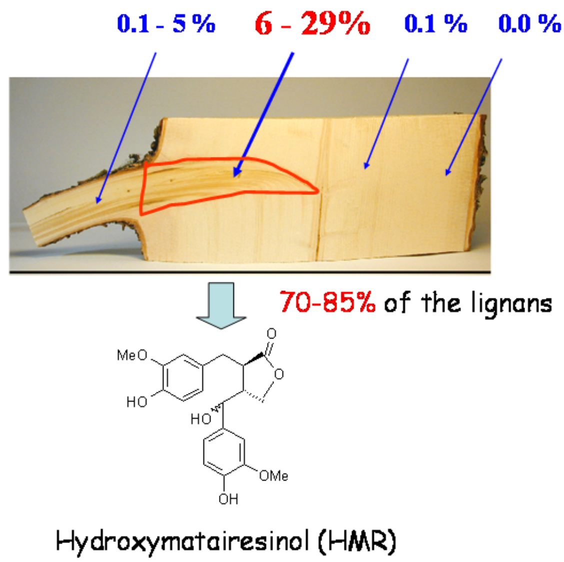

Figure 2. Typical distribution of lignans in spruce wood (Picea abies).

The HMR research at University of Turku and Åbo Akademi University, and further toxicological and clinical studies made as contract research for Hormos Medical Ltd., provided necessary data for an application to the Food and Drug Administration (FDA) in USA. HMR was approved by FDA to be marketed as dietary supplement in 2004. Hormos Medical then sold a world-wide production and marketing license to Linnea S.A., a phyto-pharmaceutical manufacturing company based in Locarno, Switzerland.

The HMRlignan^{TM} product, was launched as a dietary supplement on the market in 2006. The HMRlignan is a direct, effective precursor to the lignan enterolactone. There is good scientific support also for the statements plant lignans have a positive influence on the development of breast, prostate and colon cancer that rely specifically on oestrogens in order to progress. Lignans can also help to maintain good cardiovascular health and to moderate other oestrogen-dependent health problems such as menopause symptoms and osteoporosis (www.hmrlignan.com, and references therein).

Production of HMR started in 2005. Spruce chips are taken out from paper mills and the knot material is separated according to a patented process (Eckerman and Holmbom, 2003). The knot material is then extracted and the HMR purified by precipitation at the Linnea company in Switzerland.

Research at Åbo Akademi has recently uncovered that HMR exists naturally also in cereals, oilseeds and nuts (Smeds et al., 2007). Actually, it was found to be the dominant lignan in wheat, triticale, barley, corn, amaranth, millet and oat bran. This new finding that HMR is a common lignan in foods validates that it is a good choice for inclusion in functional foods.

Research on HMR and other lignans, such as secoisolariciresinol present in flaxseed products, is presently growing fast. Most biomedical studies have so far been carried out *in vitro*, using cell cultures, and *in vivo*, utilising animal models. Additional data are now needed on activities and effects on humans.

Other Potential Bioactive Compounds from Knots

In addition to spruce knots, knots in many other tree species have been investigated; so far knots in about 60 tree species have been studied (Holmbom et al., 2003; 2007). In almost all of the species, the knots have been found to contain substantially higher concentrations of polyphenols than ordinary stemwood, for many species 20-100 times more. Knots of softwood species commonly contain 5-15% (w/w) of polyphenols, with lignans as the dominating group.

Some tree species also contain large amounts of flavonoids and stilbenes. For example, pines (*Pinus*) contain mainly the stilbene pinosylvin and the lignan nortrachelogenin (NTG), firs (*Abies*) the lignan secoisolariciresinol, larches (*Larix*) the lignan lariciresinol and the flavonoid dihydroquercetin, and aspen species (*Populus*) the flavonoids naringenin and dihydrokaempferol. These studies have documented that knots constitute a very rich source of a wide variety of polyphenols, maybe the richest source in all of nature.

Research is continuing on extractives from knots and bark. The chemistry of the extractives is largely explored, although there are still very many tree species that could be analysed. Regarding biological effects and mechanisms there is still much to do, especially regarding effects on humans. A focus in the research is the effects of various lignans on prostate and breast cancer. For example, very recently the lignans matairesinol and nortrachelogenin were found to sensitize prostate cancer cells to TRAIL-induced apoptosis (Peuhu et al., 2010).

Concluding Remarks

Trees are the most long-lived organisms on earth, and therefore contain high concentrations of specific bioactive defense substances in certain tissues. Some tree extracts have been known for their health-promoting properties since ancient times, such as for example various terpenoid resins.

Other tree substances have been identified by scientists more recently and have been documented to exert promising health-promoting effects. Chios mastic gum traditionally has been regarded as an anti-cancer agent, especially against tumors of the breast, liver, stomach, spleen, and uterus.

It has already been associated with cardiovascular protection. Recent studies demonstrating that Chios mastic gum induces apoptosis and possesses antiproliferative activity in human colon cancer cells in vitro.

Knots and bark in trees are extremely rich sources of bioactive polyphenols, in particular of various lignans, stilbenes and flavonoids. Many of these polyphenols have recently been found promising for abating or preventing western life-style diseases such as breast and prostate cancers, and diabetes.

Certain polyphenols extracted from trees are already marketed widely as nutritional supplements and may also be introduced in specialty, functional food products, like the xylitol and sitosterol products that have been marketed world-wide for more than ten years.

Conclusion

In this chapter we began by discussing how the relationship between people and the natural world has evolved. Today a functional, scientific discourse overlies, but does not overwhelm, more complex constructions derived from tradition, religion and culture.

From our exploration of research in Norway and elsewhere we can see that exposure to natural environments and outdoor activity can have a therapeutic effect that operates at three levels. Firstly there is the positive mental re-adjustment and physical and mental fitness that comes both from reflection and from engaging in physical tasks in an attractive outdoor setting. Second, natural settings provide a positive backdrop for social interaction where shared experience and shared values can help a person readjust their self image and become more positive about themselves and their value to others. Whilst this is probably true of other settings, natural outdoor environments are often readily available, are accessible at little or no cost and usually sufficiently extensive to allow privacy or social interaction as a matter of choice. The third mechanism in place was to do with learning and reflection that led participants to change their lifestyles to deliver long-term positive benefits.

Most Europeans today, perhaps as many as 75% (EEA, 2006) have urban lifestyles and values. Even those who live in the country are likely to work in the town. Typically only about 3% of Europeans actually work in primary land and marine-based industries. The human environment in Europe today is urban, and this urban environment is highly important for human health and wellbeing. It is now well documented not only that cities can be highly stressful because of noise, activity and disturbance but also they can be hazardous where heat stress and pollution can directly impact health. Green areas can significantly reduce these effects and trees - urban forests – are the most effective green component.

The environmental footprints of major European cities are very extensive. London, for example, has been reported (GLA, 2002) to impact an area twice as large as the UK itself. Green areas and urban forests contribute by reducing the energy needs of buildings for cooling in summer or heating in winter. They are also likely to be the natural environments that people know best, and from which they can learn about their impacts on the wider natural world.

When considering how disabled people can access natural places and experience the benefits we have identified we need first to understand that they are not members of a unified category or group. Disability is personal to the individual. How a person thinks about his or her disability and manages its implications is unique to them. Land managers need to understand this diversity and plan and manage their resources accordingly.

Trees are among the world's longest-lived organisms. An individual tree must endure and survive possibly centuries of microbial and insect attack. It is no surprise that they have evolved sophisticated chemical arsenals to protect themselves. These chemicals have formed the basis of many traditional medicines and we are still discovering new properties and uses for traditional products such as tree-derived tars, tannins, resins and gums. It seems likely that there are many new biologically active chemicals still to be discovered.

Developed countries dedicate a large part of their national incomes to healthcare. If existing resources such as forests, trees and parks can be managed to deliver health benefits and medicines then even if they are quite small, or affect relatively few people, the absolute value of these benefits will represent a very large sum of money. To understand how to maximise such benefits and to deliver them in the locations and to the people who most need them requires current research interest to be maintained. This in turn requires true cross-disciplinary approaches that will be difficult to design and sustain but in the long term will repay their investment time and time again.

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