Forests for Public Health

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Edited by

Christos Gallis (Χρίστος Γαλλής του Θωμά)
and Won Sop Shin

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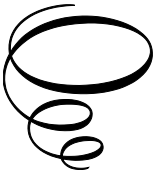

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This book dedicated to the memory of my beloved father
Thomas Gallis – Θωμάς Γαλλής

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PREFACE

FORESTS FOR PUBLIC HEALTH: A GLOBAL INNOVATIVE PROSPECT FOR THE HUMANITY

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Urbanization and modern lifestyle changes have diminished possibilities for human contact with nature in many societies. At the same time, many societies today face increasing incidence of poor physical and mental health associated with chronic stress, insufficient physical activity and exposure to anthropogenic environmental hazards that cannot be addressed by medicine and technology alone.

Contributing factors include increasingly sedentary occupations and lifestyles, increasing levels of mental stress related to urban living and contemporary work practices, and hazardous urban environmental conditions such as noise, heat stress, and air-pollution. They contribute not only to public health problems and increased expenditures for health care systems, but also lower productivity at work, increased work absenteeism, and other costly outcomes.

Natural elements and spaces such as trees, forests, urban and peri-urban forests, urban parks, gardens and green spaces have been seen as providing opportunities to ameliorate such trends. There is a growing body of evidence on positive relations between exposure to such natural environments and diverse human health indicators. One key message emerging is that contact with nature improves psychological health by reducing pre-existing stress levels, enhancing mood, enabling the recovery of cognitive abilities like directed attention, and in other ways supporting restorative processes and protecting them from the effects of future stressors.

Additionally, urban and ex-urban forests and green spaces may provide walkways and spaces for nature-based activities that may have not only

preventive effects on the life-style related diseases but also enhance people's health in general.

Walking and other nature-based activities are related to positive mood, increased sustained attention and cognitive function as well as reduced physiological stress (e.g. heart rate, blood pressure, blood sugar, stress hormones, depression, anxiety etc.) and improved physiological functions (e.g. NK cells activity, immune system, cardiovascular etc.).

Air pollution may affect the respiratory system, cardiovascular system, nervous system, urinary system, digestive system, and detrimentally affect a developing foetus during pregnancy. Urban forests may absorb a part of this urban air pollution and thus contribute to improving public health. For these and other reasons, then, public health interventions should consider the value of forests and green spaces in urban planning and design. A key message is that cities can enhance public health through urban green planning.

In sum forests, urban forests and other green spaces may be incorporated into public health systems and policies to promote mental and physical health and reduce morbidity and mortality in residents by supporting relaxation and stress alleviation, stimulating social cohesion, encouraging physical activity, and reducing exposure to air pollutants, noise and excessive heat.

Human health and wellbeing are vital socio-political and public health issues for today and for the future. They vitally define our lives. Forests, urban forests, and green spaces can have a significant influence on the health and wellbeing of many people. We might look at them as a kind of health insurance!

The Global Message: Forests, city forests and other green spaces should be incorporated to International Organizations policies and to National Public Health systems, policies and practices for a Healthy and Sustainable society.

Key words: Public Health, Forests, urban and peri-urban forests, parks and green spaces, planning, urbanization and health problems, mental and physical human health, wellbeing.

PART 1.

FORESTS AS A PART OF THE PUBLIC HEALTH SYSTEM

CHAPTER ONE

INTRODUCTION OF FOREST MEDICINE-EFFECTS OF FOREST BATHING/ SHINRIN-YOKU ON HUMAN HEALTH

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Abstract

Humans have enjoyed forest environments for ages because of the quiet atmosphere, beautiful scenery, mild climate, pleasant aromas, and fresh, clean air. In Japan, since 2004, serial studies have been conducted to investigate the effects of forest environments (Forest Bathing/ Shinrin-Yoku) on human health. We have established a new medical science called Forest Medicine. The Forest Medicine is a new interdisciplinary science, belonging to the categories of alternative medicine, environmental medicine and preventive medicine, which studies the effects of forest environments (Forest Bathing/Shinrin-Yoku/Forest Therapy) on human health. It has been reported that Forest Bathing/Shinrin-Yoku (forest therapy) has the following beneficial effects on human health:

1 Forest Bathing/Shinrin-Yoku (forest therapy) increases human natural killer (NK) activity, the number of NK cells, and the

intracellular levels of anti-cancer proteins, suggesting a preventive effect on cancers.

2 Forest Bathing/Shinrin-Yoku (forest therapy) reduces blood pressure and heart rate showing preventive effect on hypertension.

3 Forest Bathing/Shinrin-Yoku (forest therapy) reduces stress hormones, such as urinary adrenaline and noradrenaline and salivary/serum cortisol contributing to stress management.

4 Forest Bathing/Shinrin-Yoku (forest therapy) increases the activity of parasympathetic nerves and reduces the activity of sympathetic nerves to stabilize the balance of autonomic nervous system.

5 Forest Bathing/Shinrin-Yoku (forest therapy) increases the levels of serum adiponectin and dehydroepiandrosterone sulfate.

6 In the Profile of Mood States (POMS) test, Forest Bathing/ Shinrin-Yoku (forest therapy) reduces the scores for anxiety, depression, anger, fatigue, and confusion, and increases the score for vigor, showing preventive effects on depression.

These findings suggest that Forest Bathing/Shinrin-Yoku (forest therapy) may have potential preventive effects on lifestyle-related diseases.

What is Forest Medicine?

Imagine a new medical science that could let you know how to be more active, more relaxed, healthier and happier with reduced stress and reduced risk of lifestyle-related diseases and cancers by visiting forests. This new medical science is Forest Medicine. Forest Medicine studies 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 (Li, 2012). Forest Medicine is an evidence-based preventive medicine. The term of Forest Medicine in Japanese (Shinrin Igaku) was first proposed in 2006. The term of Forest Medicine in English was first used when the Japanese Society of Forest Medicine was established in 2007 (http://forest-medicine.com/). Forest Medicine is developed from forest bathing or shinrin-yoku and forest therapy. Forest Therapy is also developed from forest bathing (shinrin-yoku), which is a research-based healing practice through immersion in forest environments with the aim of promoting mental and physical health and improving disease prevention while at the same time being able to enjoy and appreciate the forest. Forest therapy is

defined as a proven forest bathing (shinrin-yoku) effect (https://www.fo-society.jp/).

What is Shinrin-Yoku/Forest Bathing?

Researchers in Japan have tried to find preventive effects against lifestyle-related diseases from forests and have proposed a new concept called "Shinrin-Yoku/Forest Bathing".

Shinrin-Yoku is translated into Forest Bathing in English. Shinrin in Japanese means 'forest', and yoku means 'bath'. So shinrin-yoku means bathing in the forest atmosphere, or taking in the forest through our senses. This is not exercise, or hiking, or jogging. It is simply being in nature, connecting with it through our sense of sight, hearing, taste, smell and touch. Shinrin-yoku is like a bridge. By opening our senses, it bridges the gap between us and the natural world (Li, 2018).

Why forest bathing/shinrin-yoku is necessary?

In 1984, the word 'technostress' was coined to describe unhealthy behaviour around new technology. Technostress can arise from all manner of everyday usage, like checking your phone constantly, compulsively sharing updates and feeling that you need to be continually connected. Symptoms run from anxiety, headaches, depression, mental fatigue, eye and neck strain to insomnia, frustration, irritability and loss of temper (Anderson, 1985). Since the year 2000, we have officially become an urban species. The urban population worldwide grew from just 746 million in 1950 to 3.9 billion in 2014, according to the United Nations Population Division. By 2050, 75% of the world's projected 9 billion population will live in cities (Li, 2018). 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, the percentage of workers with anxiety and stress was more than 50% in 1982, 62.8% in 1997, 58% in 2007, and 60.9 in 2012 (Li, 2012) (Fig. 1), suggesting a major mental health problem. Stress can induce almost all lifestyle-related diseases, such as cancers, hypertension, depression, cardiovascular diseases (myocardial infarction), stroke (cerebral haemorrhage), gastric ulcer, obesity, alcoholism, panic disorder, eating disorder (Li and Kawada, 2014). Moreover, according to the National Police Agency of Japan, more than 30000 people have

committed suicide every year since 1998; in 2007, there were 33093 reported suicides, 14,684 of which were due to health problems including 6,060 due to depression (Li, 2012). Since 2006, metabolic syndrome has become a focus of public attention in Japan (Kadota et al., 2007). The Ministry of Health, Labour and Welfare of Japan calculated that metabolic syndrome or pre-stage metabolic syndrome affected approximately 20 million Japanese people in 2006, including about 50 % of middle-aged males and 20 % of middle-aged females (http://www.mhlw.go.jp/bunya/kenkou/seikatsu/06.html). 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. There is also the phenomenon known as *karoshi*, or death from overwork in Japan. In 2016, the Ministry of Health, Labour and Welfare of Japan released a Cabinet-endorsed white paper on the extent of working overtime in Japan. Almost 23 per cent of companies said their employees worked more than eighty hours of overtime a month. Of those companies, 11.9% said some employees worked more than a hundred hours of extra time a month (Li, 2018). It is urgent to establish preventive measures against stress and lifestyle-related diseases; however, effective prevention methods have not been established. The forest environment has long been enjoyed for its quiet atmosphere, beautiful scenery, calm climate, clean fresh air and special good smell. Empirically, forest environments may reduce stress and have a relaxing effect; therefore, walking in forest parks may have beneficial effects on human health. Based on the above background, in Japan, a national health programme for forest-bathing or shinrin-yoku began to be introduced in 1982 by the Forest Agency of Japan for the stress management of workers in Japan. In 2005, the author conducted the first forest bathing study in Iiyama, Ngano prefecture in Japan and the terms of forest bathing and Shinrin-yoku in English were first named and defined by author in this study (Li et al., 2007). Forest bathing is also a short leisurely visit to a forest field, 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 (Li et al., 2007, 2008ab, Li and Kawada, 2011). Because forests occupy 67% of the land in Japan, forest bathing is easily accessible (Li et al., 2008c). 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/Shinrin-yoku

People can enjoy the forest bathing through all five senses:

1. Sense of sight: green color, yellow color and red color, forest landscape, etc,
2. Sense of smell: special good smell, fragrance from trees and flowers, phytoncides.
3. Sense of hearing: forest sounds, listen to the birds singing and the breeze rustling in the leaves of the trees.
4. Sense of touch: touching trees, put your whole body in the forest atmosphere,
5. Sense of taste: eating foods and fruits from forests, taste the fresh air in forests.

Ten tips for forest bathing have been proposed by the author as follows (Li, 2012):

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 are 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.

Why is forest medicine necessary?

Although a national health programme for forest-bathing or shinrin-yoku began to be introduced in 1982 by the Forest Agency of

Japan, there has not been sufficient medical evidence supporting the beneficial effects of forest bathing. This is due to technical limitations regarding measurements, and evidence-based evaluations as well as a lack of therapeutic menu of forest bathing. Against this background, the Japanese Society of Forest Therapy was established in 2004 (https://www.fo-society.jp/) for conducting the evidence-based research on the effects of forest environments on human health. 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. Some people study forests, some people study medicine, I study forest medicine to find the beneficial effects of forest bathing on human health.

Evidence-based Forest Medicine

In Japan, since 2004, serial studies have been conducted to investigate the effects of forest bathing/shinrin-yoku (forest environments) on human health by the project team. We have obtained a vast amount of data, proving that forest bathing promotes both physical and mental health by reducing stress (Li, 2012).

Forest bathing/Shinrin-yoku can increase human natural killer (NK) activity and the number of NK cells and the intracellular levels of anti-cancer proteins, such as perforin, granzymes and granulysin.

Effect of forest bathing on human NK activity in male subjects

In the first forest bathing study (Li et al., 2007a), 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 (Li et al., 2007b). 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 (photo 1). 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 (photo 2). 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 and the numbers of NK cells. NK cell activity went up from 17.3% to 26.5% with a 53.2% increase. NK cell numbers went up from 440 to 661 with a 50% increase. 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 (Li et al., 2002, 2004, 2005b, 2008d, Okada et al., 2003). In order to explore the mechanism of enhancement of NK activity induced by the forest bathing, the effect of forest bathing on the intracellular levels of perforin, GRN, and GrA/B in peripheral blood lymphocytes (PBL) were investigated, and it was found that the forest bathing also significantly increased the numbers of intracellular perforin-, GRN-, and GrA/B-expressing lymphocytes. The presence of anti-cancer protein GRN was up by 48%, GrA by 39%, GrB by 33%, and perforin by 28%. Taken together, these findings indicate that forest bathing 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 (Li et al., 2007a). Han et al., (2016) and Tsao et al., (2018) also reported that forest bathing increased human NK activity and supported our findings.

Does a trip to places without forest (a city tourist visit) also increase human NK activity?

Although a forest bathing trip boosted human NK activity, does a trip to places without forest (a city tourist visit) also increase NK activity? Thus, to investigate whether taking a trip (city tourist visit) can also affect human NK activity, eleven healthy male subjects, aged 35-56 years, participated in a three-day/two-night trip to Nagoya city in mid-May, 2006 (Li et al., 2008a). Information on the subjects was gathered from a self-administered questionnaire, including age and lifestyle habits as described previously (Li et al., 2007b). 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 (Li et al., 2008a). 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. The results showed that 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 (Li et al., 2008a).

How long does the increased NK activity last after a forest bathing trip?

Forest bathing, but not a city trip indeed boosted human NK activity; however, how long does the increased NK activity last after a forest bathing trip? Thus, an investigation was conducted to address this question (Li et al., 2008a). 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 (Li et al., 2007b). The subjects experienced a three-day/two-night trip to three different *Chamaecyparis obtuse* (Japanese cypress, Hinoki in Japanese) forest parks, the birthplace of forest bathing (shinrin-yoku) in Japan, around Agematsu town in Nagano prefecture located in northwest Japan in early September, 2006 (photo 3). The schedule of the forest bathing trip was similar to that described previously (Li et al., 2007a). 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, the numbers of NK cells, and the percentages of GRN-, perforin-, and GrA/B-expressing cells in PBL, which confirmed the previous findings (Li et al., 2007a). The increased NK activity, number of 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, even 30 days (Li et al., 2008a). 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. It is very important in the preventive medicine.

Effect of forest bathing 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 a forest bathing trip also increases NK activity in female subjects. It has been reported that menstrual cycle significantly affects NK activity (Souza et a., 2001); therefore, the influence of menstrual cycle on NK activity should be controlled for in experiments with female subjects.

In this study (Li et al., 2008b), 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 (photo 4). The schedule of the forest bathing trip and blood/urine sampling was similar to that described previously (Li et al., 2007a, 2008a). 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, perforin-, GRN-, and GrA/B-expressing cells. 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 (Li et al., 2008b), which confirmed the previous findings in male subjects (Li et al., 2008a). 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.

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 (Roszkowski et al., 1997, Souza et a., 2001, Szekeres-Bartho et al., 2005). 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 (Li et al., 2008b).

Many factors, including circadian variation (Angeli, 1992), physical

exercise (Ochshorn-Adelson et al., 1994), and alcohol consumption (Ochshorn-Adelson et al., 1994, Li et al., 2007b) 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 (Li et al., 2007a, 2008ab, 2009, 2010). 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.

A day trip to a forest park also increased human NK activity

Although a three-day/two-night forest bathing 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. 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 (Li et al., 2010). 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 and the numbers of NK, perforin, GRN, and GrA/B-expressing cells 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. In fact, NK activity was

increased after day 1 in three-day/two-night forest bathing (Li et al., 2007a, 2008ab); therefore, the day trip of forest bathing (Li et al., 2010) reproduced the previous findings (Li et al., 2007a, 2008ab).

The increased NK activity and anti-cancer proteins lasted for more than 7 days, even 30 days after the trip (Li, 2010, Li et al, 2007, 2008ab, 2010). 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. NK cells are immune cells and play an important role in 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 (Imai et al., 2000), indicating the importance of NK cell function on cancer prevention. Therefore, it suggests that forest bathing may have the preventive effect on cancers.

These findings indicate that forest therapy increased NK activity by the following pathways (Fig. 1) (Li 2010).

(1) Forest therapy directly acts on NK cells by phytoncides released from trees and induces increases in the number of NK cells and the levels of intracellular anti-cancer proteins such as perforin, GRN, and GrA/B.

(2) Forest therapy indirectly increases human NK activity, the number of NK cells and the levels of intracellular anti-cancer proteins by reducing stress hormones.

Because NK cells can kill tumor cells by releasing anti-cancer proteins, such as perforin, GRN, and GrA/B, and forest therapy increases NK activity and the intracellular level of anti-cancer proteins, the above findings suggest that forest therapy may have a preventive effect on cancer generation and development.

2. Forest bathing/Shinrin-yoku can reduce stress hormones, such as adrenaline, noradrenaline and cortisol and may contribute to stress management (Li et al., 2008ab, 2010, 2011). The concentrations of adrenaline and noradrenaline in urine have been used to evaluate work related stress in nurses (Brown et al., 2006) and lorry drivers (van der Beek et al., 1995), in which the subjects showed decreases in adrenaline and/or noradrenaline in urine with the lower stress.

3. Forest bathing/Shinrin-yoku can reduce systolic and diastolic blood pressures and heart rate and may have preventive effect on hypertension (Li et al., 2011, 2016, Ochiai et al., 2015a).

Many reports have found that forest environments reduced the levels of blood pressure in middle-aged subjects with high-normal blood pressure (Li et al, 2011, Mao et al., 2012, Ochiai et al., 2015, Ideno et al 2017, Yu

et al., 2017).

Li et al. (2011) investigated the effects of forest environments on blood pressure in sixteen male subjects with higher blood pressure without taking antihypertensive drug (mean age: 57.4±11.6 years) 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. As shown in Fig. 3, 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. The reductions in blood pressure after walking in a forest environment were 7 mmHg for both SBP (from 141 to 134 mmHg), and DBP (from 86 to 79 mmHg). This suggests that walking in the forest park, but not in the urban area reduced blood pressure and that forest therapy has a potential preventive effect on hypertension.

Mao et al (2012) also found the beneficial effect of forest bathing on blood pressure. In this study, twenty-four elderly patients with essential hypertension were randomly divided into two groups of 12. One group was sent to a broad-leaved evergreen forest to experience a 7-day/7-night trip, and the other was sent to a city area in Hangzhou for control. Blood pressure indicators, cardiovascular disease-related pathological factors including endothelin-1, homocysteine, renin, angiotensinogen, angiotensin II, angiotensin II type 1 receptor, angiotensin II type 2 receptor as well as inflammatory cytokines interleukin-6 and tumor necrosis factor α were detected. As results, subjects who walked in the forest environment showed a significant reduction in blood pressure in comparison to that of the city group. The values for the bio-indicators in subjects exposed to the forest environment were also lower than those in the urban control group and the baseline levels of themselves. They concluded that forest bathing has therapeutic effects on human hypertension by inhibiting the renin-angiotensin system and inflammation. In addition, Ochiai et al (2015a) and Yu et al. (2017) also found that forest bathing can reduce blood pressure on middle-aged males with high-normal blood pressure.

Moreover, Ideno et al (2017) conducted a systematic review and meta-analysis including twenty trials involving 732 participants on the effect of Shinrin-yoku on the blood pressure. Both systolic and diastolic blood pressures of the forest environment was significantly lower than that of the non-forest environment showing a significant effect of Shinrin-yoku on reduction in blood pressure.

Mechanism of forest therapy on the effect of blood pressure

As shown in Figure 4, forest therapy reduces blood pressure by the following mechanisms:

1) Forest therapy reduces blood pressure by reducing stress hormone levels, such as urinary adrenaline, urinary noradrenaline (Li et al., 2008ab, 2010, 2016), salivary cortisol (Park et al., 2010), and blood cortisol (Li et al., 2010) levels. It is well known that stress hormones such as adrenaline, noradrenaline and cortisol increase blood pressure level.
2) Forest therapy reduces blood pressure by reducing sympathetic nerve activity and by increasing parasympathetic nerve activity. Sympathetic nerve activity can be determined by measuring the levels of urinary adrenaline and/or noradrenaline (Moleman et al., 1992, Li et al., 2008ab), and there are significant correlations between blood pressure and urinary adrenaline and noradrenaline levels (Mena-Martín et al., 2006). In addition, many studies (Park et al. 2010, Ochiai et al 2015b, Li et al 2016) reported that forest viewing and walking in forests significantly reduced sympathetic nerve activity and increased parasympathetic nerve activity compared to performing the same activities in an urban environment. 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.
3) Forest therapy reduces blood pressure by inhibiting the renin-angiotensin system (Mao et al. 2012).
4. Forest bathing/Shinrin-yoku can increase the activity of parasympathetic nerve and reduce the activity of sympathetic nerve showing relaxing effects (psychologically calming effects) (Park et al., 2010, Tsunetsugu et al., 2010, Ochiai et al, 2015b, Song et al.,

2015, 2017, Li et al., 2016).

5. Forest bathing/Shinrin-yoku can reduce the symptoms for anxiety, depression, anger, fatigue and confusion and increased the vigor in the Profile of Mood States (POMS) test in both male and female subjects. In addition, forest bathing is particularly effective against mental stress (mental fatigue) (Li, 2012, Li et al, 2007, 2008b, 2010, 2016, Takayama et al., 2014, Park et al., 2010, Tsunetsugu et al., 2010, Ochiai et al, 2015b, Song et al., 2015, 2017). This suggests forest bathing has a preventive effect on those in a depressed state.
6. Forest bathing/Shinrin-yoku can improve sleep quality (Li, 2012, Morita et al., 2011).
7. Forest bathing/Shinrin-yoku can reduce blood sugar level in type 2 DM (diabetes mellitus) patients (Ohtsuka et al., 1998).
8. Forest bathing/Shinrin-yoku can increase the level of serum adiponectin. Adiponectin is a serum protein hormone specifically produced by adipose tissue. Studies have shown that lower blood adiponectin concentrations are associated with several metabolic disorders, including obesity, type 2 DM (diabetes mellitus), cardiovascular disease, and metabolic syndrome (Li et al, 2011). Recent studies have suggested that adiponectin shows anti-tumorigenesis activity in several cancers, including prostate, breast, endometrial, brain, and colon cancer (Karnati et al., 2017, Otani et al., 2017).
9. Forest bathing/Shinrin-yoku significantly increase serum dehydroepiandrosterone sulfate (DHEA-S) levels (Li et al., 2011). 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 (Bjørnerem et al., 2004, Tsai et al., 2006). Epidemiological evidence in humans suggests that DHEA-S has cardioprotective, antiobesity, and antidiabetic properties (Tsai et al., 2006).
10. It has been reported that people living in areas with lower forest coverage have significantly higher standardized mortality ratios (SMRs) of cancer than people living in areas with higher forest coverage. There are significant inverse correlations between the percentage of forest coverage and the SMRs of lung, breast, and uterine cancers in females, and the SMRs of prostate, kidney, and colon cancers in males in all prefectures in Japan, even after the effects of smoking and socioeconomic status are factored in. These findings indicate that increased forest coverage may partially

contribute to a decrease in mortality due to cancer in Japan (Li et al., 2008c).

11. Phytoncides released from trees significantly increased human NK activity in vitro in a dose-dependent manner and significantly increased the intracellular levels of perforin, GrA, and GRN in human NK cells (Li et al., 2006).
12. Phytoncide exposure significantly increased human NK activity and the numbers of NK, perforin, GRN, and GrA/B-expressing cells, 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 (Li et al., 2009).
13. It has been reported that stress may induce and/or exacerbate many lifestyle-related diseases, such as cancers, hypertension, ischemic heart disease, gastrointestinal ulcer, and depression (Li and Kawada 2014). Forest therapy can reduce stress hormone levels, such as urinary adrenaline, urinary noradrenaline (Li et al., 2008ab, 2010, 2016), salivary cortisol (Park et al., 2010), and blood cortisol (Li et al., 2010) levels suggesting that forest therapy may have preventive effects on lifestyle-related diseases mediated by reducing the stress hormones.

Why did the forest environment affect human health? What kind of factors in the forest environment contribute to beneficial effects on human health? The quiet atmosphere, beautiful scenery, mild climate, special good smell, and fresh, clean air in forests contribute to the effects. It is the total effect from all five senses: senses of sight, smell, hearing, touch and taste. In fact, sense of smell by breathing in volatile organic substances, called phytoncides from trees, such as α-pinene and limonene has a bigger effect (Li et al., 2006, 2009).

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 (Li, 2012).
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 (Li, 2012, Li et al., 2006, 2007, 2008ab, 2009).

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 (Li, 2012). 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 (Osgood, 1962). 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.

Forest Medicine should investigate the effect of forest environments on human health 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, adrenaline and noradrenaline), and the immune system (NK activity, intracellular anti-cancer proteins in NK cells) determined by physiological, biological, biochemical, psychological, and immunological methods (Li, 2012, Li et al, 2007, 2008bc, 2010, 2016, Bratman et al., 2015). Recent technological developments have enabled us to conduct the above investigations in a forest field.

(2) Data/evidence obtained from epidemiological studies, i.e., investigations on the effect of exposure to forests and natural environments (green space) on human health, the morbidity and mortality rates of diseases (Li et al., 2008c, Mitchell and Popham, 2008, Barton and Pretty, 2010, Kardan et al., 2015).

Forest Medicine in the future

In 2007, the Japanese Society of Forest Medicine was established for the purpose to support the Forest Medicine research in Japan (http://forest-medicine.com/). In 2010, the International Society of Nature and Forest Medicine (INFOM) was established for the purpose to support

the Forest Medicine research and expand the philosophy and concept of Forest Medicine in the world (http://infom.org).

Based on the above background, I would like to propose the following international collaborations on Forest Medicine in the future.

1. To expand the philosophy and concept of Forest Medicine over the world.
2. To verify the preventive effects of Forest Medicine on lifestyle-related diseases in the world.
3. To establish an international accreditation system for Forest Medicine specialist and Forest Therapist.
4. To establish the Shinrin-yoku/Forest bathing as a treatment for some lifestyle-related diseases.
5. To incorporate the Forest Medicine into rehabilitation and physical Medicine.

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