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Review

New Concept of Forest Medicine

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Abstract: Forest bathing was proposed in Japan in 1982 for the purpose of reducing stress and health management, and research on the health promotion and disease prevention effects of forest bathing began in Japan in 2004. Since then, the author's research team has published many papers and, in 2012, established Forest Medicine as a new preventive 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 a reduced risk of lifestyle-related diseases. This new medical science is Forest Medicine. Forest Medicine studies the effects of forest environments on human health and is a new interdisciplinary science that belongs to the categories of environmental and preventive medicine. On the other hand, more than 10 years have passed since then, and a lot of evidence has been obtained and many articles regarding Forest Medicine have been published. Therefore, in this review, the author proposes a new concept of Forest Medicine, based on the new evidence and published papers, with the psycho-neuro-endocrino-immune network in mind.

Keywords: blood pressure; endocrine system; forest bathing; Forest Medicine; immune system; natural killer (NK); nervous system; psycho-neuro-endocrino-immune network; profile of mood states (POMS); Shinrin-yoku; stress hormone

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1. What Is the Psycho-Neuro-Endocrino-Immune Network?

Traditional medicine has considered the nervous system, endocrine system, and immune system to be independent of each other. However, given the advances in the field of psychology and neuropsychology during the last few decades [1,2], 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 (Figure 1) [3]. Conversely, the activation of certain brain neurons results in immunoregulatory neuroendocrine responses. Evidence indicates that brain-borne cytokines, such as IL-1 and IL-6, mediate such reciprocal effects to a large extent [4]. 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 [5,6]. On the other hand, immune cells release cytokines, which, in turn, signal to the central and peripheral nervous system [7]. 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 [4].

As shown in Figure 2A, when people experience stress, tension and anxiety are generated in the brain, which induces a disturbance of the autonomic nervous system, secretes stress hormones, and suppresses the immune function. A suppressed immune response feeds back to the autonomic nervous system to further amplify the stress response.

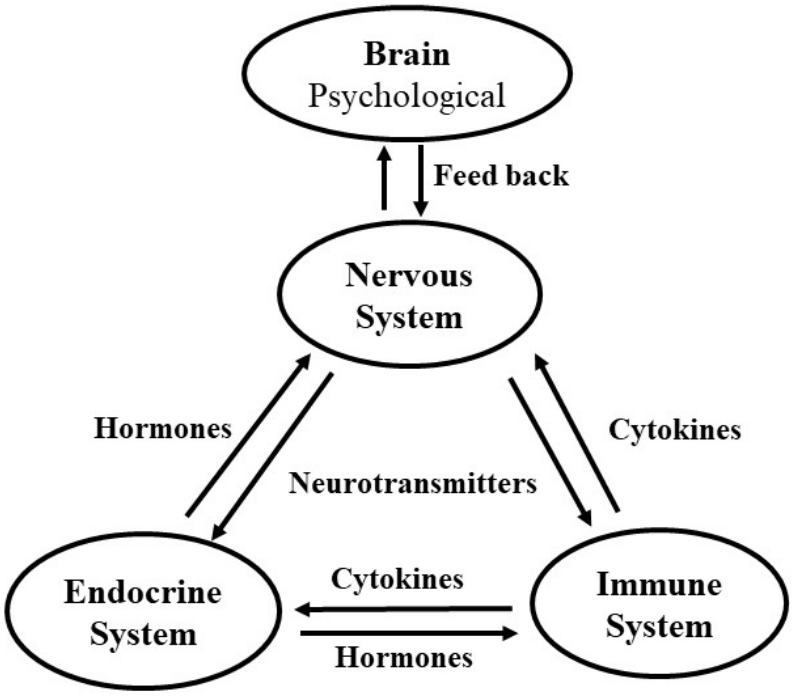
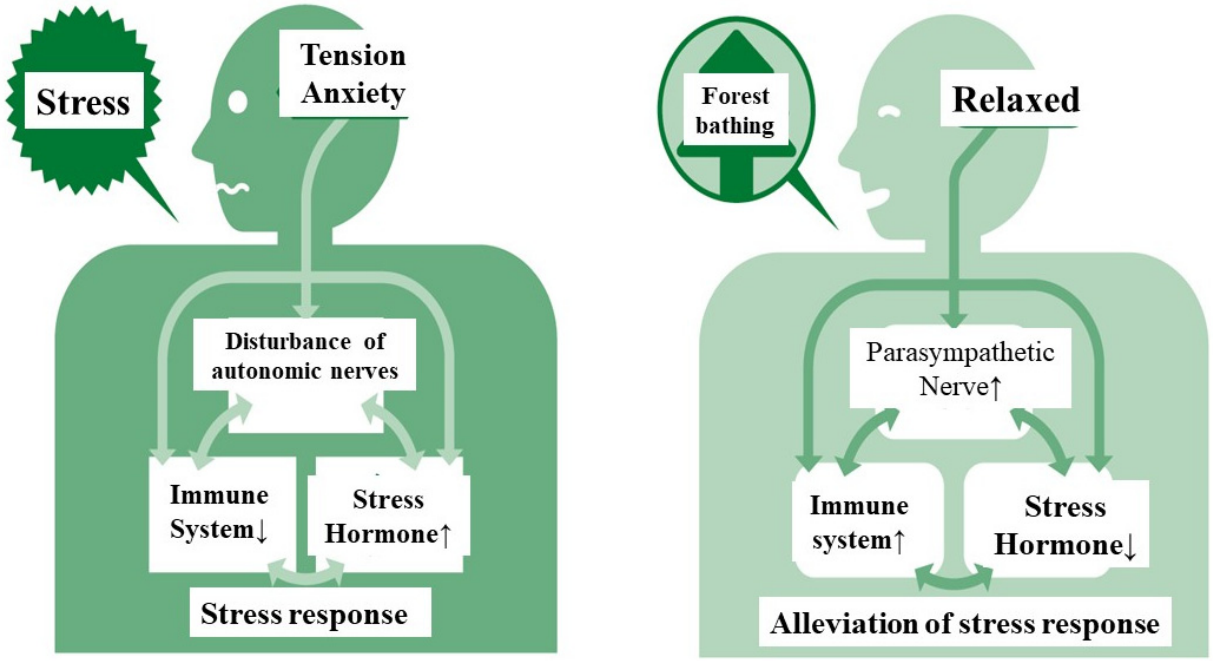


Figure 1. The psycho-neuro-endocrino-immune network.



A. Physiological and psychological reactions to stress

B. Physiological and psychological reactions during forest bathing

Figure 2. This figure shows the feedbacks among the nervous system, endocrine system, and immune system on physiological and psychological reactions to stress (**A**) and to forest bathing (**B**), respectively [8]. Cited and modified from Shinrin-yoku (Japanese) [8].

As shown in Figure 2B, when people practice forest bathing, the brain is relaxed, the parasympathetic nervous system is dominant, the secretion of stress hormones is suppressed, and the immune function is enhanced. An elevated immune response feeds back into the autonomic nervous system to further reduce the stress response.

Using the information above as a basis, this paper will review the effects of forest bathing/Shinrin-yoku on the human psycho-neuro-endocrino-immune network and propose a new concept of Forest Medicine.

2. What Is Forest Bathing/Shinrin-Yoku?

Humans have enjoyed forest environments for ages because of the quiet atmosphere, beautiful scenery, mild climate, pleasant aromas, and fresh, clean air. 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" [3,9–12].

Shinrin-yoku is translated into forest bathing in English. Shinrin in Japanese means 'forest', and yoku means 'bath'. Therefore, Shinrin-yoku means bathing in a forest atmosphere or taking in the forest through our senses. This is not exercise, i.e., hiking or jogging. It is simply being in nature, connecting with it through our senses 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 [9–12]. People can enjoy forest bathing through all five senses of sight, smell, hearing, touch, and taste [3,12] (Figure 3).

Figure 3. Female subjects enjoying forest bathing.

Forest bathing includes the following elements (Figure 4):

1. Forest bathing improves human health and prevents diseases by stimulating the five senses (human health).
2. Understanding the importance of planting trees and protecting forests through forest bathing activities (forest health).
3. Contributing to regional economic development and environmental conservation through forest bathing activities (community health).

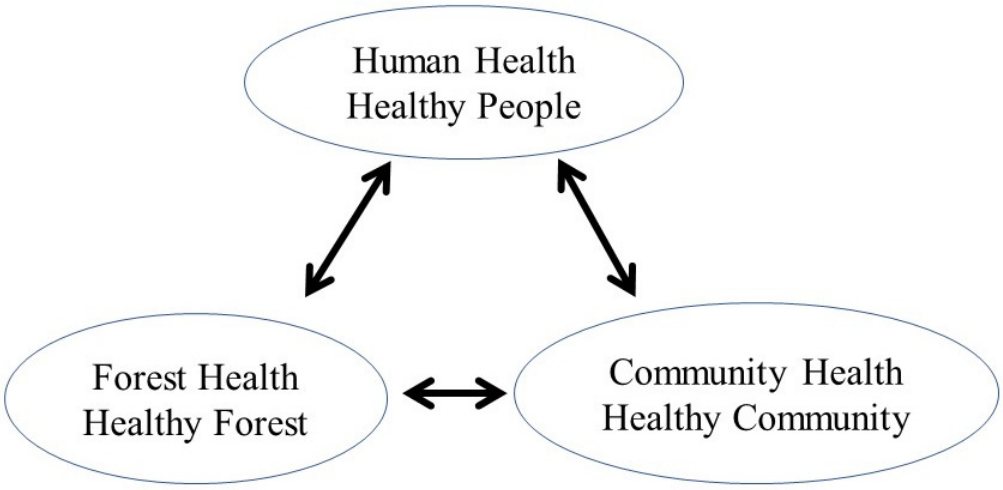


Figure 4. Philosophy of forest bathing.

3. Necessity of Forest Bathing/Shinrin-Yoku

Stress is a keyword in understanding the necessity of forest bathing. In 1984, the word 'technostress' was coined to describe unhealthy behavior associated with new technology [13]. In Japan, the prevalence of cancers and lifestyle-related diseases such as heart disease, diabetes, cerebrovascular disease, and hypertension are increasing [14], and more than half of deaths are attributed to lifestyle-related diseases [15]. Stress can induce almost all lifestyle-related diseases, such as cancers, hypertension, depression, cardiovascular diseases, stroke, gastric ulcer, obesity, alcoholism, panic disorder, eating disorders, and so on [16]. 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 the prevention of diseases is needed. It is urgent to establish preventive measures against stress and lifestyle-related diseases. Empirically, forest environments may reduce stress and have a relaxing effect; therefore, walking in green parks may have beneficial effects on human health. Based on the above background, in 2005, my research team conducted the first forest bathing study in Japan and the terms of Shinrin-yoku and forest bathing in English were first named and defined by myself (the author of this study) [9]. Forest bathing can also consist of a short leisurely visit to a forest for the purpose of relaxation and the breathing in of volatile substances called phytoncides derived from trees, such as alpha-pinene and limonene [9,17–19]. Because forests occupy 67% of the land in Japan, forest bathing is easily accessible [20]. Currently, the terms "Shinrin-yoku" and "Forest bathing" are internationally accepted because both "Shinrin-yoku" and "Forest bathing" are the titles of English books [10,11] and books in other languages [21–44].

4. What Is Forest Therapy?

Forest Therapy was developed from forest bathing (Shinrin-yoku), which is a research-based healing practice that involves immersing oneself in forest environments with the aim of improving mental and physical health as well as disease prevention while at the same time being able to enjoy and appreciate the forest environment. Forest therapy is defined as a proven Shinrin-yoku effect. The Japanese Society of Forest Therapy was established in 2004 for certifying forest therapy bases in Japan. In fact, 65 forest therapy bases have been certified so far in Japan (https://www.fo-society.jp/, accessed on 1 March 2023). Forest therapy, which originated in Japan, is now spreading all over the world [45]. In the International *Handbook* of *Forest Therapy*, research and practices of forest therapy in Japan, Korea, China, Malaysia, Australia, Norway, Sweden, Germany, Austria, and Switzerland were introduced [45].

5. 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 a reduced risk of experiencing lifestyle-related diseases and cancers simply 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 that belongs to the categories of alternative medicine, environmental medicine, and preventive medicine [3]. Forest Medicine was developed from forest bathing/Shinrin-yoku and is an evidence-based preventive medicine [12].

6. 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 researchers. My research team, and other researchers, have obtained a vast amount of data that proves that forest bathing improves both physical and mental health by reducing stress [3,12].

We should understand Forest Medicine through the psycho-neuro-endocrino-immune network, as shown in Figure 1.

7. Effect of Forest Bathing on the Autonomic Nervous System

The autonomic nervous system is made up of the sympathetic nervous system (the 'fight or flight' part, which gets your heart going) and the parasympathetic nervous system (the 'rest and recover' part, which calms everything down). Common sense tells us that spending time in nature helps us relax and feel calm [46]. 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 [47]. Heart rate variability (HRV), as well as blood pressure and pulse rate, is 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 [48]. Sympathetic nervous activity also can be determined by measuring the levels of urinary adrenaline and/or noradrenaline [49], and there are significant correlations between blood pressure and urinary adrenaline and noradrenaline levels [47]. It has been reported that forest bathing reduces sympathetic nervous activity, increases parasympathetic nervous activity, and regulates the balance of autonomic nerves [50–52]. As a result, forest environments reduce blood pressure and heart rate and have relaxing effects [50–53]. 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 [9,17–19,54,55].

8. Effect of Forest Bathing on the Endocrine System (Hormones)

The endocrine system secretes various hormones, including stress hormones, such as adrenaline, noradrenaline, and cortisol [3,8].

9. Effects of Forest Bathing on Stress Hormones

There are three kinds of stress hormones: adrenaline (which mainly indicates mental stress), noradrenaline (which mainly indicates physical stress), and cortisol (which can indicate both) [12,46]. Adrenaline is released from the adrenal medulla, and the adrenaline level increases under circumstances of novelty, anticipation, unpredictability, and general emotional arousal, whereas noradrenaline is the predominant neurotransmitter released by the sympathetic system, and some of this enters the blood; the level of noradrenaline increases during increased physical activity [49]. Cortisol is released by the hypothalamic–pituitary–

adrenal axis in response to stress [51]. My research team has found that forest bathing and phytoncides can reduce stress hormones, such as adrenaline, noradrenaline, and cortisol, and may contribute to stress management [17,18,53–55] (Figure 5). In addition, because the effect of forest bathing on adrenaline was greater than that on noradrenaline, the effect on mental stress was greater than that on physical stress [3,12,18]. Other researchers have also reported that forest bathing reduced cortisol in saliva [50–52], supporting our findings.

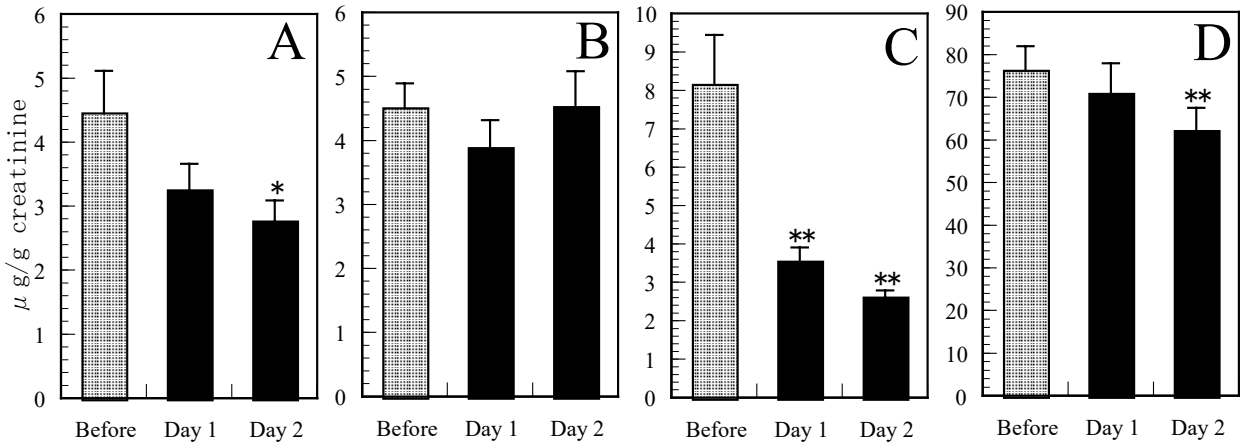


Figure 5. Effect of a forest bathing trip on adrenaline and noradrenaline concentrations in urine. (**A**): Effect of a forest bathing trip on urinary adrenaline concentrations in males (n = 12). (**B**): Effect of a city trip on urinary adrenaline concentrations in males (n = 11). (**C**): Effect of 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 [17] and Li et al. J Biol Regul Homeost Agents. 2008; 22: 45–55 [18] with permission from Biolife.

10. Effects of Forest Bathing on Other Hormones

Forest bathing also significantly increase serum adiponectin and dehydroepiandrosterone sulfate (DHEA-S) levels [53]. Adiponectin is a serum protein hormone specifically produced by adipose tissue. Studies have shown that blood adiponectin concentrations that are lower than normal are associated with several metabolic disorders, including obesity, type 2 diabetes mellitus, cardiovascular disease, and metabolic syndrome [56]. Levels of DHEA and DHEA-S, the major secretory products of the adrenal gland, decline dramatically with age and are concurrent with the onset of degenerative changes and chronic diseases associated with aging [57,58]. Epidemiological evidence in humans suggests that DHEA-S has cardioprotective, anti-obesity, and anti-diabetic properties [57]. In addition, forest bathing also increases the level of serotonin in serum [59]. On the other hand, forest bathing did not affect serum estradiol and progesterone levels in females, or serum insulin, FT3 (free triiodothyronine), and TSH (thyroid-stimulating hormone) levels in males [3].

11. Effects of Forest Bathing on Blood Pressure and Heart Rate through Autonomic Nervous System and Stress Hormones

Clinically, adrenaline, noradrenaline, and cortisol, which are stress hormones, are biomolecules that raise blood pressure. Therefore, the sympathetic nerve and stress hormones such as adrenaline, noradrenaline, and cortisol increase blood pressure [47,51]. Forest bathing reduces the activity of sympathetic nerve and stress hormones [17,18,50–53,55,60]; therefore, I hypothesized that forest bathing may reduce blood pressure and heart rate by reducing stress hormones. In fact, many reports have found that forest environments reduced the levels of blood pressure in middle-aged subjects with a high–normal blood pressure [53,61–66].

To prove my above hypothesis, my research team studied the effects of forest bathing on blood pressure in male subjects with a higher blood pressure without taking antihypertensive drugs [53]. As shown in Figure 6, blood pressure levels in the green park were significantly lower than those in the urban area. However, there were no significant differences in blood pressure levels while subjects were walking between the urban area and the forest. The reductions in blood pressure after walking in a forest environment were 7 mmHg for both systolic blood pressure (SBP) (from 141 to 134 mmHg) and diastolic blood pressure (DBP) (from 86 to 79 mmHg). This antihypertensive effect is comparable to that of antihypertensive agents (Figure 6). Furthermore, forest bathing has no side effects and is free compared to antihypertensive drugs (there are no costs associated with forest bathing). This is a three birds-with-one-stone effect. This suggests that walking in the green park but not in the urban area reduced blood pressure and that forest bathing has the potential to prevent hypertension.

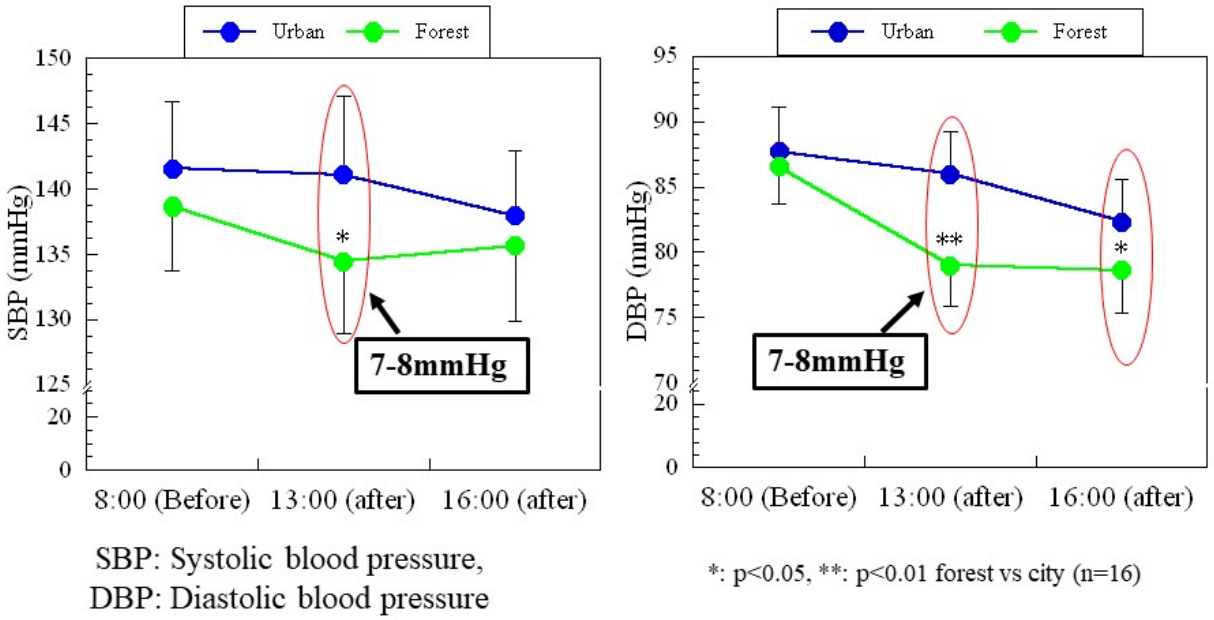


Figure 6. Forest bathing significantly reduces blood pressure compared with city walking. Blood pressure was decreased about 7–8 mmHg by forest bathing.

Mao et al. [62] also found that forest bathing has therapeutic effects on human hypertension by inhibiting the renin–angiotensin system and inflammation in elderly patients. In addition, Ochiai et al. [61] and Yu et al. [63] also found that forest bathing can reduce blood pressure in middle-aged males with a high–normal blood pressure. Moreover, Ideno et al. [64] conducted a systematic review and meta-analysis that included twenty trials involving 732 participants on the effect of forest bathing on the blood pressure, and found that forest bathing significantly reduced blood pressures. Yau and Loke [65] also reviewed the physiologically and psychologically relaxing effects of forest bathing on middle-aged and elderly people with pre-hypertension and hypertension, indicating the preventive effect of forest bathing on hypertension. We also found that forest bathing reduced heart rate in middle-aged males [60]. Recently, Huang et al. [66] reported the adjunctive therapeutic effects of forest bathing on geriatric hypertension in *Cinnamomum camphora* forest environment in China in four seasons, suggesting that the effect of forest bathing with regards to lowering blood pressure was particularly pronounced during summer and autumn.

Taken together, forest bathing reduces blood pressure and heart rate by the following mechanisms (Figure 7):

(1) Forest bathing reduces blood pressure by reducing stress hormone levels, such as urinary adrenaline, urinary noradrenaline [17,18,53,55,60], salivary cortisol [50–52],

and cortisol in serum [55]. It is well known that stress and stress hormones such as adrenaline, noradrenaline, and cortisol increase blood pressure level.

(2) Forest bathing reduces blood pressure by reducing sympathetic nerve activity and by increasing parasympathetic nerve activity [50–52,60]. Sympathetic nerve activity can be determined by measuring the levels of urinary adrenaline and/or noradrenaline [17,18,67], and there are significant correlations between blood pressure and urinary adrenaline and noradrenaline levels [47]. In addition, many studies [50–53,60,61,68] have reported that forest viewing and walking significantly reduced sympathetic nerve activity and increased parasympathetic nerve activity compared to urban environments.

(3) Forest bathing reduces blood pressure by inhibiting the renin–angiotensin system [62].

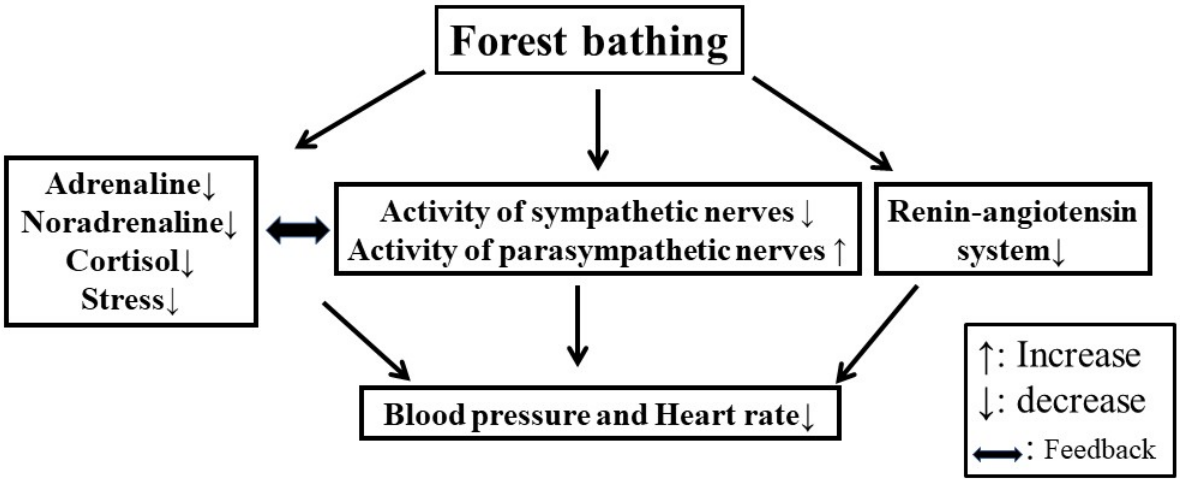


Figure 7. Mechanism of forest bathing on blood pressure and heart rate.

12. Effect of Forest Bathing on Sleep

It has been reported that stress and higher activity of sympathetic nerves can induce sleep disorders [10,12,16]. Forest bathing can reduce stress and the activity of sympathetic nerves [17,18,50–53,55,60]; therefore, forest bathing may improve sleep by reducing stress and the activity of sympathetic nerves.

Several studies investigated the effect of forest bathing on sleep [3,8,59,68,69]. It has been reported that forest bathing significantly increased sleep time in middle-aged male office workers [3]. Recently, my research team found that forest bathing significantly improves the levels of sleepiness one feels upon waking up, leading to a greater refreshed feeling (recovery from fatigue) and indicating that forest bathing may improve sleep quality [8,59]. In addition, two hours of forest bathing improved nocturnal sleep conditions for individuals with sleep complaints, possibly as a result of exercise and emotional improvement [68]. Moreover, Kim et al. found that forest therapy could be a good alternative to nonpharmacological treatment for mitigating insomnia in postmenopausal women [69].

13. Potential Preventive Effects of Forest Bathing on Depression through the Psycho-Neuro-Endocrino-Immune Network

Stress and sleep disorder are two keywords to consider when trying to understand the causes of depression and the relationship with forest bathing. Stress and sleep disorder can induce many mental diseases, including depression [10–12,16]. It is widely known that patients with depression often experience sleep disorders, and sleep disturbance is a common and key symptom that affects most of patients with depression [70,71]. Stress also can induce sleep disorder to induce depression [12,16,59]. On the other hand, forest bathing can reduce stress [3,17,18] and improve sleep [3,59]. Therefore, forest bathing may

have a preventive effect on depression by reducing stress and by improving sleep [17,18,59]. The balance of autonomic nerves is also a keyword to understand the background of depression and the relationship with forest bathing. The autonomic nerves are made up of the sympathetic system and the parasympathetic system. Imagine you are walking along the street and a saber-toothed tiger jumps out at you. Your fight-or-flight responses will start up. Your heart will beat faster, your blood pressure will increase, and your digestion will slow down. When you are relaxing, by, for example, going for a forest bath, the opposite happens. Your blood pressure decreases, your pulse rate slows, and the rate of digestion can speed up. Additionally, as well as increasing blood pressure and heart rate, stress also throws the two parts of the nervous system out of balance. It strengthens the fight-or-flight part and suppresses the rest-and-recover part, meaning we are constantly on high alert [10,11]. The higher activity level of sympathetic nerves and disturbance on the balance of autonomic nerves can induce many mental diseases, including depression and sleep disorder [12,16,59]. On the other hand, forest bathing can reduce the activity of sympathetic nerves, increase the activity of parasympathetic nerves, and stabilize the balance of autonomic nerves. Therefore, forest bathing may have a preventive effect on depression by stabilizing the balance of autonomic nerves.

Forest bathing can reduce negative emotions and increase positive feelings in both male and female subjects [3,9,18,50–53,55,60,68,72–77]. In addition, forest bathing is particularly effective against mental stress (mental fatigue) [3,18]. Li et al. [59] reported that forest bathing significantly increased the levels of serotonin in serum and significantly increased the score for vigor while decreasing the score for fatigue in the profile of mood states (POMS) test. Park et al. [77] also reported that forest bathing programs increased serotonin in serum in middle-aged women. It has been reported that patients with depression show lower levels of serotonin in serum [78–82]. Furuyashiki et al. [83] conducted a comparative study of the physiological and psychological effects of a day-long session of forest bathing on working-age people with and without depressive tendencies, which demonstrated significantly positive effects on mental health, especially in those with depressive tendencies. In addition, a study from Stanford University reveals a pathway by which nature experiences may improve mental well-being and suggests that accessible natural areas within urban contexts may be a critical resource for improving mental health in our rapidly urbanizing world [84]. Moreover, Kotera et al. [85] conducted a systematic review and meta-analysis and suggested the beneficial effects of Shinrin-yoku (forest bathing) and nature therapy on mental health. Taken together, as shown in Figure 8, forest bathing has a preventive effect on subjects in a depressed state through the psycho-neuro-endocrino-immune network. For the future, it is necessary to verify the effect of forest bathing in depressed patients. In fact, such studies are currently being planned.

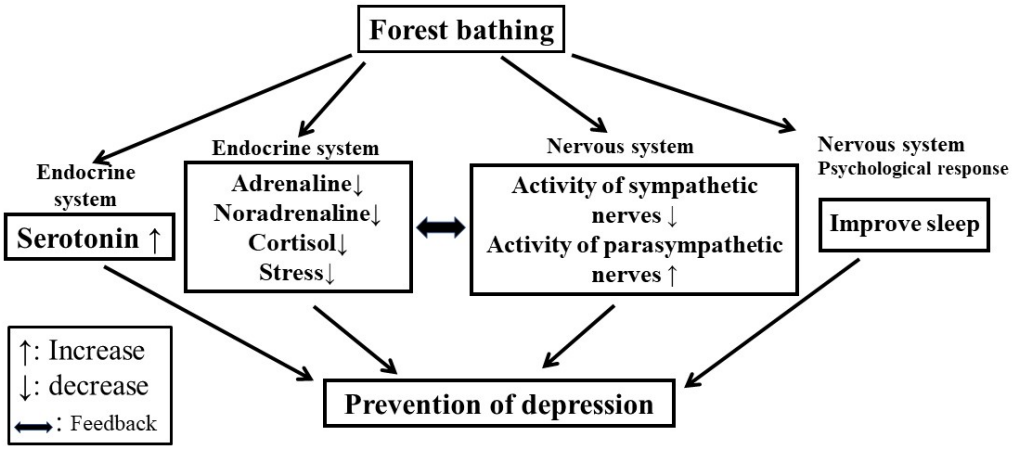


Figure 8. Mechanism of forest bathing for the prevention of depression.

14. Effects of Forest Bathing on the Immune System

The immune system, including natural killer (NK) cells, plays an important role in defending against bacteria, viruses, and tumors [86]. Stress inhibits immune function [87] and forest bathing may reduce stress; therefore, the author speculated that forest bathing may have beneficial effects on immune function by reducing stress [3]. Thus, we conducted several experiments to investigate the effects of forest bathing on human immune function to prove my hypothesis. The main findings are as follows:

1. Three-day/two-night forest bathing significantly increased human NK activity, the number of NK cells, and percentages of perforin, granzymes A/B(GrA/B), and granulysin (GRN)-positive cells in both males and females [9,17,18]. Moreover, the increased NK activity, number of NK cells, and percentages of GRN-, perforin-, and GrA/B-positive cells lasted more than 7 days and even for 30 days in both males and females [17,18] (Figures 9 and 10). Han et al. [88] and Tsao et al. [89] also reported that forest bathing increased human NK activity, supporting our findings.
2. One-day forest bathing also significantly increased human NK activity, the number of NK cells, perforin, GRN, and GrA/B-expressing cells, and the increased NK activity lasted for seven days after the trip [55]. In fact, NK activity increased after the first day of the three-day/two-night forest bathing [9,17,18]; therefore, one-day forest bathing [55] reproduced these previous findings [9,17,18].
3. On the other hand, the city trip did not increase human NK activity, the number of NK cells, perforin, GRN, or GrA/B-positive cells, indicating that increased NK activity during forest bathing was not due to the trip itself, but due to the forest environments [17].
4. Phytoncides, such as isoprene, α-pinene, and β-pinene, were detected in the forest air [9,17,18,55]. Moreover, phytoncides released from trees significantly increased human NK activity and the intracellular levels of perforin, GrA, and GRN in human NK cells both in vivo [54] and in vitro [90].
5. Forest bathing and phytoncide exposure in vivo significantly decreased the concentrations of stress hormones such as adrenaline and noradrenaline in urine [17,18] and cortisol in serum [55], indicating that phytoncide and decreased stress hormone levels contributed to the increased NK activity [54].
6. It has been reported that people with higher NK activity showed a lower incidence of cancers, whereas people with lower NK activity showed a higher incidence of cancers [91], indicating the importance of NK cell function with regards to cancer prevention. Therefore, these findings suggest that forest bathing may have a preventive effect on cancers.
7. We also found that people living in areas with lower forest coverage have significantly higher standardized mortality ratios of cancers such as lung, breast, and uterine cancers in females and prostate, kidney, and colon cancers in males in Japan. This indicated that increased forest coverage may partially contribute to a decrease in mortality due to cancer in Japan [20]. Interestingly, higher forest coverages were also associated with lower impacts of infectious diseases in other parts of the globe [92].
8. These findings indicate that forest bathing increased NK activity by the following pathways [93] (Figure 11):
    (1) Forest bathing directly acts on NK cells via phytoncides released from trees and induces an increase in the number of NK cells as well as the levels of intracellular anti-cancer proteins such as perforin, GRN, and GrA/B.
    (2) Forest bathing indirectly increases human NK activity, the number of NK cells, and the levels of intracellular anti-cancer proteins by reducing stress hormones.

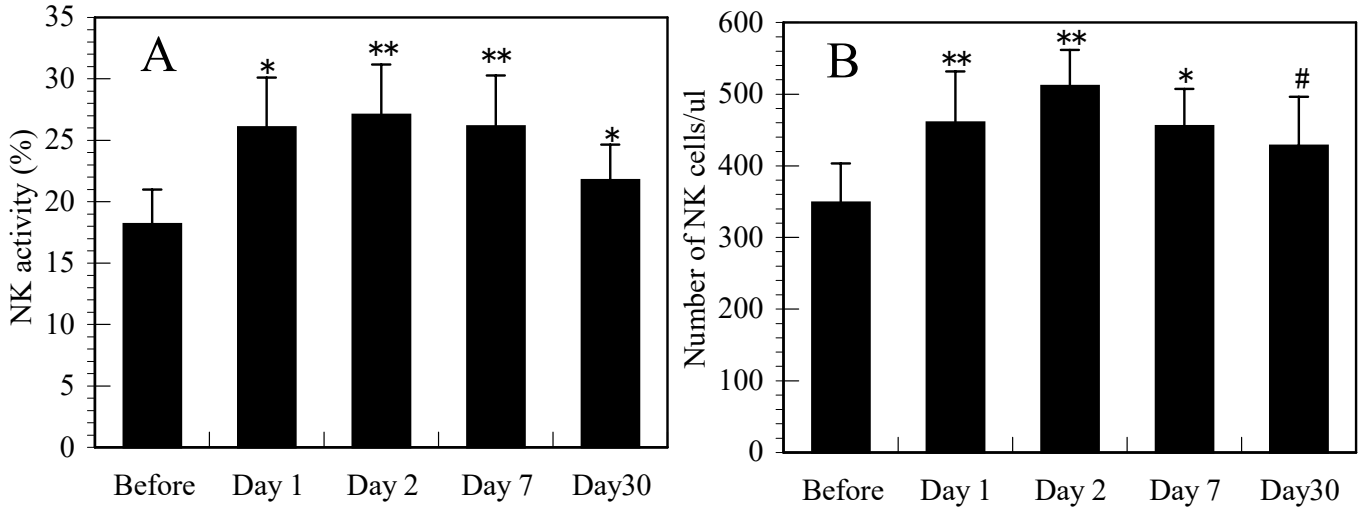


Figure 9. Effect of a forest bathing trip on NK activity (**A**) and the number of NK cells (**B**) in males. Data are presented as the mean + SE (n = 12). *: $p < 0.05$, **: $p < 0.01$, #: $p = 0.054$ significantly different from before the trip by paired *t*-test. Cited from Li et al. Int J Immunopathol Pharmacol. 2008; 21: 117–128 [17] with permission from Biolife.

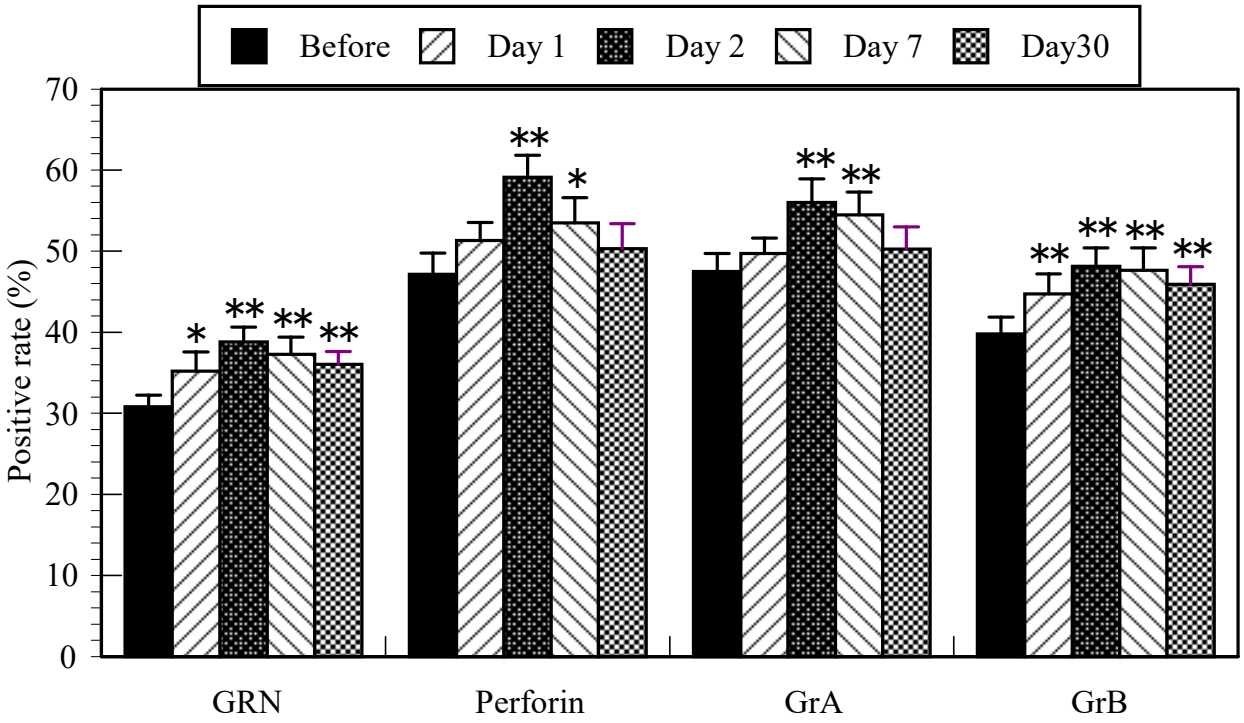


Figure 10. Effect of a forest bathing trip on the positive rates of GRN, perforin, and GrA/B-expressing cells in PBL in males. Data are presented as the mean + SE (n = 12). *: $p < 0.05$, **: $p < 0.01$, significantly different from before the trip by paired *t*-test. Cited from Li et al. Int J Immunopathol Pharmacol. 2008; 21: 117–128 [17] with permission from Biolife.

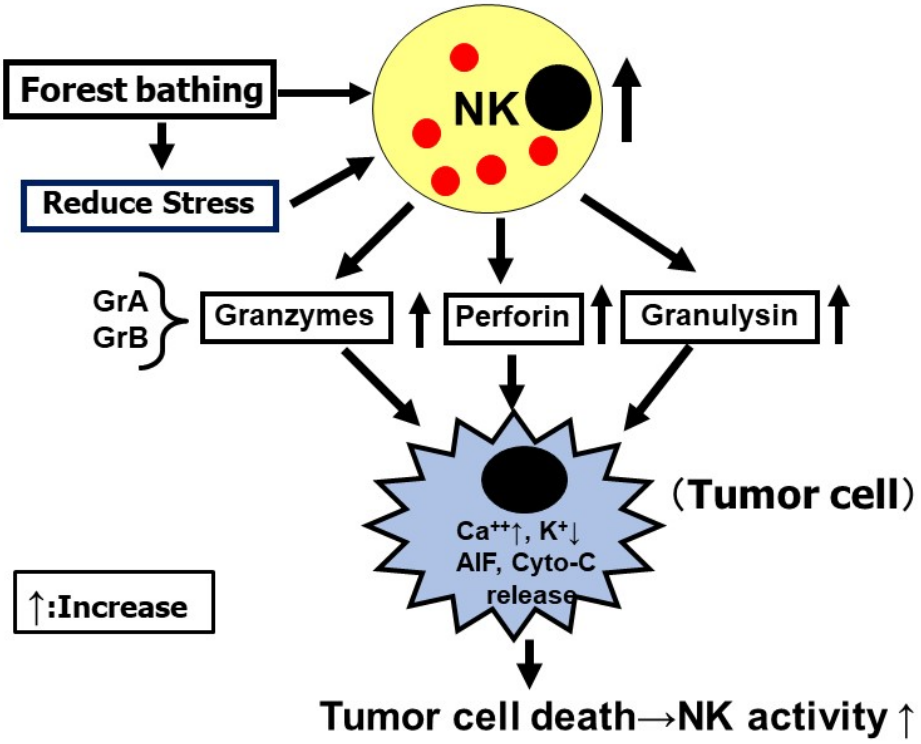


Figure 11. Mechanism of forest bathing-induced NK activity.

15. Preventive Effects of Forest Bathing on Lifestyle-Related Diseases

Stress may induce and/or exacerbate many lifestyle-related diseases, such as cancers, hypertension, ischemic heart disease, gastrointestinal ulcers, and depression [16]. Forest bathing can reduce stress hormone levels, such as urinary adrenaline, urinary noradrenaline [17,18,55,60], salivary cortisol [50–52], and blood cortisol [55] levels, suggesting that forest bathing may have preventive effects on lifestyle-related diseases mediated by reducing stress hormones. It has been reported that forest bathing reduces blood pressure and heart rate, showing preventive effects on hypertension and heart diseases [53,59–66]. Mao et al. [94,95] reported the beneficial effects of forest bathing as an adjunctive therapy for elderly patients with chronic heart failure. Moreover, Jia et al. [96] discussed the health effects of forest bathing on elderly patients with chronic obstructive pulmonary disease. It has also been reported that forest bathing effectively decreases blood glucose levels in type 2 DM (diabetes mellitus) patients and shows a preventive effect on type 2 DM [97]. In addition, forest bathing shows potential preventive effects on depression by reducing stress hormones [17,18,50–53,55,60], reducing negative emotions (such as anxiety, depression, anger, fatigue, and confusion), and by increasing the level of serotonin in serum and positive feelings such as vigor [3,9,18,50–53,55,59,60,68,69,72–77,85]. Forest bathing-induced increases in the level of serum adiponectin [53,60] and DHEA-S [53] also contribute to this effect. Moreover, forest bathing may have preventive effects on cancers by increasing the number of anti-cancer proteins in NK cells, such as perforin, granulysin, and granzymes [9,17–19,54,55].

16. Forest Bathing May Apply to Rehabilitation Medicine

Depression is reportedly the most common mental disorder following stroke and after an acute orthopaedic injury, with an incidence ranging from 10 to 64% [98–100]. Based on the above information, the prevention of depression in rehabilitation hospitals is a big challenge. However, effective prevention methods have not been established at present. It has been reported that forest bathing shows preventive effects on depression [3,9,18,50–53,55,59,60,68,69,72–77,85]. My research team also found that walking in city parks in Tokyo reduced negative emotions, increased positive feelings, and

showed a relaxing effect both in male and female subjects [3,8], suggesting that forest bathing in city parks may have a potential preventive effect on depression. Thus, the author investigated the relaxing effect of forest bathing on patients undergoing rehabilitation by advising them to walk in a Japanese garden. The results indicated that forest bathing in a Japanese garden reduces the scores of anxiety, depression, anger, fatigue, and confusion, whereas there were increases in the score of vigor among patients, suggesting that forest bathing may apply to stress management and depression prevention [8,12,101,102]. Kang et al. [103] also reported that forest bathing improved the condition of patients with chronic posterior neck pain. In addition, Ochiai et al. [104] measured the psychophysiological effects of nature therapy (stimulation with bonsai trees) on adult male patients with spinal cord injuries and found that forest bathing can lead to a state of physiological and psychological relaxation in patients with spinal cord injuries. The above studies suggest the possibility of forest bathing being applied as a rehabilitative medicine, as suggested by another study [105]. However, further studies in this area are needed.

17. Potential Preventive Effects of Forest Bathing on COVID-19

Elderly people and patients with underlying diseases such as diabetes, hypertension, heart diseases, and respiratory diseases are more susceptible to COVID-19 and experience severe cases. The mortality rate is also higher among the elderly and those with underlying health conditions because of the reduced immune function in these patients [106]. Therefore, forest bathing may have a preventive effect on COVID-19 infection by boosting immune system function [93]. Mental stress and mental disorders induced or exacerbated by "lockdown" and "isolation" are also major social problems [107]. Forest bathing reduces negative emotions, mental stress, and stress hormones and increases vigor [3,9,18,53,59,60]. In fact, virtual exposure to forest environments based on audio-visual stimuli via a short computer video showing forest environments, with an urban environment video as a control, proved effective in reducing negative emotions such as anxiety among people in limited spaces due to lockdown in Italy during the COVID-19 pandemic [107]. Kim et al. also reported the positive effects of a Forest Healing Program in a Korean forest on emotional stress and sleep quality for exhausted medical workers during the COVID-19 Outbreak in Korea [108]. Roviello and Roviello [109] reported that a lower COVID-19 mortality in Italian forested areas points towards immunoprotection by Mediterranean plants, suggesting the influence of green spaces on the prevention of COVID-19. Timko Olson et al. [110] reported that, during the COVID-19 pandemic, mindfulness associated with forest bathing was specifically important to at-risk groups, those experiencing depression, loneliness, and social isolation, and people with high levels of stress, suggesting the importance of Forest Medicine in post-COVID-19 health management and disease prevention. Moreover, Roviello et al. [92] reviewed the efficacy of forest bathing and physical activity as weapons against COVID-19, suggesting the potential preventive effect of forest bathing on COVID-19. Wajchman-Świtalska et al. also reported that urban green spaces can reduce COVID-19-induced mental stress in Poland [111]. In addition, Muro et al. [112,113] also found the psychological benefits of forest bathing during the COVID-19 pandemic in Spain. Therefore, forest bathing may have preventive effects on COVID-19-induced mental stress and mental disorders. Forest bathing also has preventive effects on hypertension and heart diseases [53,60], further preventing COVID-19 in patients with these conditions.

Taken together, forest bathing may play a very important role in the prevention of COVID-19 by boosting immune system function and reducing mental stress in post-COVID-19 health management and disease prevention. However, further studies in this area are needed.

In fact, currently, most studies have been performed using Japanese and Asian samples, while relatively few studies have been published from Europe, North America, Oceania, Africa, and South America. Therefore, more cross-cultural/cross-forestal studies on the topic are necessary to generalize the efficacy of Forest Medicine around the world and direct the future development of Forest Medicine.

18. Conclusions

Based on the above findings, I would like to propose a new concept of Forest Medicine as follows:

1. We should approach Forest Medicine by considering the psycho-neuro-endocrino-immune network.
2. Forest Medicine has become a new preventive medicine for lifestyle-related diseases.
3. Forest Medicine may be a new clinical medicine to treat some lifestyle-related diseases, such as depression, hypertension, heart diseases, sleep disorder, viral diseases, and so on, in the future.
4. Forest Medicine may be incorporated into rehabilitation medicine.
5. Based on the concept of forest bathing as shown in Figure 3, Forest Medicine should share the same philosophy as forest bathing.
6. We should expand the philosophy and concept of Forest Medicine all over the world by performing more cross-cultural/cross-forestal studies on the topic.

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