Original Research

Psychological effects of forest environments on healthy adults: Shinrin-yoku (forest-air bathing, walking) as a possible method of stress reduction

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Abstract *Objectives:* Shinrin-yoku (walking and/or staying in forests in order to promote health) is a major form of relaxation in Japan; however, its effects have yet to be completely clarified. The aims of this study were: (1) to evaluate the psychological effects of shinrin-yoku in a large number of participants; and (2) to identify the factors related to these effects.

Methods: Four hundred and ninety-eight healthy volunteers took part in the study. Surveys were conducted twice in a forest on the same day (forest day) and twice on a control day. Outcome measures were evaluated using the Multiple Mood Scale-Short Form (hostility, depression, boredom, friendliness, wellbeing and liveliness) and the State-Trait Anxiety Inventory A-State Scale. Statistical analyses were conducted using analysis of variance and multiple regression analyses.

Results: Hostility ($P < 0.001$) and depression ($P < 0.001$) scores decreased significantly, and liveliness ($P = 0.001$) scores increased significantly on the forest day compared with the control day. The main effect of environment was also observed with all outcomes except for hostility, and the forest environment was advantageous. Stress levels were shown to be related to the magnitude of the shinrin-yoku effect; the higher the stress level, the greater the effect.

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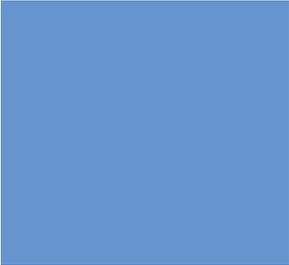
Conclusions: This study revealed that forest environments are advantageous with respect to acute emotions, especially among those experiencing chronic stress. Accordingly, shinrin-yoku may be employed as a stress reduction method, and forest environments can be viewed as therapeutic landscapes. Therefore, customary shinrin-yoku may help to decrease the risk of psychosocial stress-related diseases, and evaluation of the long-term effects of shinrin-yoku is warranted.

Introduction

Maintaining mental health is one of the main issues related to disease prevention in developed countries,[1,2] with poor mental health often associated with the occurrence and risk of certain diseases.[3–7] For this purpose, various stress management and relaxation techniques have been proposed.[8–18] In Japan, shinrin-yoku (staying and/or walking in forests in order to promote physiological and psychological health by breathing in the volatile substances released by trees) was first proposed in the 1980s and has since become a recognized relaxation activity.[19,20] Since forests occupy 64% of the land in Japan,[21] participation in shinrin-yoku is easily accessible. According to a public opinion poll conducted in Japan in 2003, 25.6% of respondents had participated in shinrin-yoku in the previous year.[22] Furthermore, 56.8% of respondents expressed a desire to spend future holidays in rural and/or mountainous forested areas, and of these, 66.6% expressed an interest in shinrin-yoku for health promotion,[22] indicating the popularity of shinrin-yoku in Japan. Moreover, shinrin-yoku is possible in forest environments anywhere in the world.

It is known that natural environments have various beneficial effects on human health. Indeed, most European health resorts catering for rehabilitation and optimization of health conditions are located in natural environments.[23] In its guidelines, the Japanese Ministry of Health, Labour and Welfare recommends regular interaction with the natural environment.[2] Natural environments are considered to be 'therapeutic landscapes'[24], i.e. places, settings, situations, locales and milieus associated with treatment and healing and the maintenance of health and wellbeing, the concept of which was developed in the 1990s.[24–26] This wide concept includes both physical environments and psychological environments such as humanistic landscapes (e.g. a sense of place).[24,25] Communal gardens for elderly people are one example of a therapeutic landscape related to the green environment.[27]

However, due to the scarcity of studies on the benefits of green environments[28,29] and shinrin-yoku, the above effects have not yet been clarified and no guidelines exist regarding what effects can be expected and how they can be maximized. Recent studies have revealed the acute psychological and physiological effects of a few hours of shinrin-yoku. For example, natural killer cell activity and immunoglobulin levels were shown to increase,[20] while systolic blood pressure and noradrenaline and cortisol levels were shown to decrease.[30] Furthermore, negative emotions have been shown to decrease and positive emotions increase after participation in Shinrin-yoku.[31] In addition, research aimed at finding a cure for diabetes has shown that walking in a forest is more effective at decreasing blood glucose levels than other activities such as exercise on a cycle ergometer or treadmill, or underwater exercise.[19]

Most of the above studies were conducted with specific subsets of up to 20 healthy participants, usually students. Since the acute effects of shinrin-yoku in a large healthy population and the factors related to these effects remain unknown, knowledge from existing studies cannot be directly applied to research in the field of public health. Therefore, the aims of the present study were: (1) to examine the acute psychological effects of shinrin-yoku in a large number of participants; and (2) to identify the factors related to these effects.

Methods

Study location and participants

The Ethics Committee of Kyoto University approved the study protocol, and written informed consent was obtained from all volunteers. This survey was conducted in Tokyo University Forest, Chiba, Japan.[32] Participants were healthy male and female volunteers aged 20 years or over who visited the forest over 4 days in November and

December 2004, and who agreed to participate. Participants were required to complete a self-administered questionnaire on two occasions whilst at the forest [once on arriving at the entrance and once after taking a walk in the forest (Forest-1 and Forest-2, respectively)] and twice on a control day (any other holiday when participants did not visit a forested area; Control-1 and Control-2, completed within 1 h before or after the times of day when Forest-1 and -2 were completed, respectively). Responses from participants who completed all four questionnaires and who did not visit a forested area on the control day were included in the analyses.

Questionnaires

Outcome measures

As there are few authorized questionnaires that can be used to measure participants' momentary emotions, the following were employed: (1) the Multiple Mood Scale-Short Form [33,34] (MMS-SF); and (2) State-Trait Anxiety Inventory A-State Scale[35,36] (STAI-S; scores range from 20 to 80). The STAI-S is used for measurements of anxiety, while the MMS, which was developed for use in Japan, is used to measure eight momentary emotions, each of which is scored using five four-point items (1 = do not feel and 4 = feel strongly); subscale scores range from 5 to 20. Cronbach's α of each MMS-SF subscale is reportedly within a range of 0.81–0.89.[34] The present survey was conducted using all eight subscales, but only the outcome measures of the positive and negative items related to health[37–43] (i.e. hostility, depression, boredom, friendliness, wellbeing and liveliness) were adopted in the analyses.

Factors related to the outcome measures

Participants provided the following information.

- *Background*: age, sex, self-rated physical health ('general health' hereinafter) and psychosocial stress level ('stress level' hereinafter) in the past couple of months,[44] level of enjoyment of walking in forests, and frequency of visits to forested areas.
- *Conditions during the forest visit*: weather, duration of stay, previous visits, accompanying person(s), activities undertaken (hiking/trekking, nature watching, photography), walking course and distance walked.
- *Conditions on the control day*: degree of physical exercise (exercised/did not exercise), subjec-

tive feelings (able/unable to take part in their favourite activities) and objective activities undertaken.

Statistical analysis

SPSS 10.0J for Windows was used for all statistical analyses. First, two-way analysis of variance (ANOVA) was conducted using the environment (E; the forest vs. control) and time of completion of each survey (T; the first survey vs. the second survey on each day). Since conditions on the control day (i.e. degree of exercise,[45,46] subjective feelings and objective activities) varied among participants, the effect on participants' emotions on the control day was considered using stratified analyses. As a result of two-way ANOVA using time of completion (Control-1 vs. Control-2) and the above conditions as variables, participants' emotions on the control day were shown to be affected by exercise and whether they were able to take part in their favourite activities, but were little affected by what they actually did on that day. Exercise and the ability to take part in their favourite activities were both shown to have a positive effect. Two-way ANOVA was therefore conducted using $E \times T$ for the following four subgroups: those who exercised and did not exercise on the control day, and those who were unable and able to take part in their favourite activities on the control day.

Determining relevant factors related to the effects of shinrin-yoku

Firstly, two-way ANOVA was conducted to determine which factors related to the way participants took part in shinrin-yoku affected the outcomes on the forest day (time of completion of Forest-1 vs. Forest-2 × the conditions of the forest visit, level of enjoyment of walking in forests, and the frequency of visits to forested areas). Next, to investigate whether participants' characteristics were related to the magnitude of the shinrin-yoku effect, three-way ANOVA was conducted using E, T and factors related to participants' characteristics (age by decade, sex, general health and stress level). Finally, stepwise multiple regression analyses were conducted using factors thought to be relevant. The dependent variable was the difference between the outcome scores of Forest-2 and Control-2, while the independent variables were sex, age, general health condition, general stress level, enjoyment of walking in forests, exercised or did

not exercise on the control day, and ability to take part in their favourite activites on the control day.

Results

In total, 541 people agreed to participate in the survey. Of these, 498 (244 males, 254 females; mean age $\pm$ SD: 56.2 $\pm$ 10.6 years) people were included in the analyses. The mean duration of stay in the forest was 2 h 20 min $\pm$ 51 min, and the mean distance walked was 5.7 $\pm$ 1.7 km. Regarding levels of enjoyment of walking in forests, 475 participants (95.4%) responded that they 'like' doing so, 20 (4.0%) chose 'no preference', and none of the participants responded that they 'dislike' walking in forests.

The outcome results are shown in Table 1. The interaction between E and T was significant with respect to four outcomes (hostility, depression, boredom and liveliness), with the forest environment being advantageous except with regard to boredom. The main effect of environment was observed on six outcomes (depression, boredom, friendliness, wellbeing, liveliness and STAI-S), with the forest environment being advantageous.

Regarding the subgroup who were unable to take part in their favourite activities on the control day ($n = 240$), a significant interaction between E and T was observed for four outcomes (hostility, depression, liveliness and STAI-S), and the environment had a significant effect on six outcomes (depression, boredom, friendliness, wellbeing, liveliness and STAI-S), with the forest environment being advantageous. Regarding the subgroup that did not exercise on the control day ($n = 320$), a significant interaction was observed for four outcomes (hostility, depression, boredom and liveliness), with the forest environment being advantageous except with regard to boredom. The main effect of environment was observed on six outcomes (depression, boredom, friendliness, wellbeing, liveliness and STAI-S), with the forest environment being advantageous. The results of the subgroups who were able to take part in their favourite activities and who exercised on the control day are shown in Table 2. Regarding the subgroup who were able to take part in their favourite activities on the control day, a significant interaction between E and T was observed for four outcomes (hostility, depression, boredom and liveliness), with the forest environment being advantageous except with regard to boredom. The main effect of environment was observed on six outcomes (hostility, boredom, friendliness, wellbeing, livelinessand STAI-S), with

the forest environment being advantageous except with regard to hostility. Regarding the subgroup that exercised on the control day, a significant interaction was observed for two outcomes (hostility and depression), and the main effect of environment was observed on five outcomes (boredom, friendliness, wellbeing, liveliness and STAI-S), with the forest environment being advantageous. That is, significant beneficial effects were observed on the forest day compared with the control day, not only for those who were unable to take part in their favourite activities and who did not exercise, but also for those who were able to take part in their favourite activities and who did exercise on the control day.

Factors related to the way in which participants took part in shinrin-yoku and characteristics related to the forest walks were shown to affect the outcomes on the forest day as follows. Significant interactions were observed between accompanying person(s), walking course, distance walked, activities undertaken and time (Forest-1 vs. Forest-2) with regard to boredom and wellbeing; wellbeing and liveliness; boredom; and boredom, respectively. No significant main effects of any of these factors were observed. No significant interaction between level of enjoyment of walking in forests and time was observed with respect to any outcome, but a significant main effect of level of enjoyment of walking in forests was observed for five outcomes (hostility, friendliness, wellbeing, liveliness and STAI-S), with the scores being better among those who like walking in forests compared with those who expressed no preference. No significant interaction was observed with the frequency of visits to forested areas, but a significant main effect of the frequency of visits to forested areas was observed for two outcomes (hostility and liveliness). No significant interaction or main effect of weather, duration of stay and previous visits were observed for weather, duration of stay or previous visits.

Characteristics related to the magnitude of the shinrin-yoku effect were shown to affect the outcomes as follows. A significant interaction between E, T and stress level was observed for three outcomes (depression, boredom and STAI-S), with more stressed participants gaining more beneficial effects. A significant interaction between E and stress level was observed for four outcomes (hostility, depression, boredom and STAI-S). The STAI-S results of each general stress subgroup are shown in Fig. 1. A significant interaction between E, T and general health was observed for two outcomes (boredom and liveliness), with the participants with the worst general health

Table 1 Outcome scores and results of two-way repeated analysis of variance.

Subscale	n	Environment	First Mean	First SD	Second Mean	Second SD	Main effect of environment F, df, P	Main effect of completion time F, df, P	Interaction F, df, P
Hostility[a]	474	Forest	6.6	2.6	5.9	1.6	0.8, 1, 0.39	60.3, 1, <0.001	15.5, 1, <0.001
		Control	6.3	2.0	6.1	1.9			
Depression[a]	482	Forest	7.8	2.8	6.6	2.1	23.9, 1, <0.001	141.5, 1, <0.001	40.6, 1, <0.001
		Control	8.0	2.9	7.5	2.7			
Boredom[a]	476	Forest	7.6	2.7	8.1	2.2	61.6, 1, <0.001	3.1, 1, 0.08	11.0, 1, 0.001
		Control	8.9	3.0	8.8	3.0			
Friendliness[b]	471	Forest	12.4	3.2	12.1	3.3	310.7, 1, <0.001	5.7, 1, 0.017	2.6, 1, 0.11
		Control	10.2	3.2	10.1	3.4			
Wellbeing[b]	462	Forest	14.9	2.8	14.5	3.0	167.6, 1, <0.001	19.3, 1, <0.001	0.6, 1, 0.43
		Control	13.0	3.1	12.7	3.2			
Liveliness[b]	476	Forest	15.4	3.0	15.8	3.1	506.8, 1, <0.001	0.7, 1, 0.42	10.9, 1, 0.001
		Control	12.5	3.3	12.3	3.4			
STAI State[a]	491	Forest	30.9	7.4	29.7	6.4	281.9, 1, <0.001	31.0, 1, <0.001	1.8, 1, 0.18
		Control	36.2	7.5	35.4	7.0			

df, degrees of freedom; SD, standard deviation; STAI, State-Trait Anxiety Inventory.
[a]The higher the score, the worse the condition.
[b]The higher the score, the better the condition.

Table 2 Results of two-way analysis of variance considering the activities undertaken on the control day.

	n	Environment	First Mean	First SD	Second Mean	Second SD	Main effect of environment F, df, P	Main effect of completion time F, df, P	Interaction F, df, P
Subgroup who were able to take part in their favorite activities on the control day									
Hostility	238	Forest	6.6	2.4	5.9	1.6	5.5, 1, 0.02	34.4, 1, <0.001	12.0, 1, 0.001
		Control	6.1	1.8	5.9	1.7			
Depression	244	Forest	7.7	2.7	6.5	2.0	1.8, 1, 0.18	60.5, 1, <0.001	26.4, 1, <0.001
		Control	7.5	2.5	7.1	2.5			
Boredom	241	Forest	7.6	2.6	8.1	2.2	4.4, 1, 0.04	3.6, 1, 0.06	8.2, 1, 0.005
		Control	8.2	2.6	8.1	2.4			
Friendliness	237	Forest	12.4	3.2	12.2	3.3	108.8, 1, <0.001	0.1, 1, 0.79	2.5, 1, 0.12
		Control	10.6	3.4	10.7	3.5			
Wellbeing	231	Forest	14.8	3.0	14.4	3.0	60.7, 1, <0.001	5.2, 1, 0.02	1.5, 1, 0.2
		Control	13.3	3.1	13.1	3.2			
Liveliness	242	Forest	15.4	3.1	15.9	3.0	139.1, 1, <0.001	6.3, 1, 0.01	4.6, 1, 0.03
		Control	13.4	3.2	13.4	3.3			
STAI State	249	Forest	30.8	7.6	29.5	6.4	93.1, 1, <0.001	27.0, 1, <0.001	0.01, 1, 0.9
		Control	34.8	7.0	33.4	6.5			
Subgroup who exercised on the control day									
Hostility	167	Forest	6.7	2.4	6.0	1.8	1.3, 1, 0.25	17.9, 1, <0.001	4.8, 1, 0.03
		Control	6.3	2.1	6.1	1.9			
Depression	168	Forest	7.9	2.8	6.6	2.2	2.6, 1, 0.11	43.1, 1, <0.001	18.1, 1, <0.001
		Control	7.7	2.8	7.4	2.7			
Boredom	164	Forest	7.7	2.6	8.0	2.2	4.4, 1, 0.04	1.3, 1, 0.26	0.8, 1, 0.37
		Control	8.3	2.8	8.3	2.6			
Friendliness	167	Forest	12.8	3.2	12.5	3.3	93.7, 1, <0.001	1.6, 1, 0.21	2.2, 1, 0.14
		Control	10.8	3.5	10.8	3.6			
Wellbeing	158	Forest	14.8	2.9	14.5	2.9	38.0, 1, <0.001	3.2, 1, 0.08	0.02, 1, 0.90
		Control	13.3	3.0	13.1	3.3			
Liveliness	166	Forest	15.7	3.0	16.0	3.1	79.0, 1, <0.001	0.4, 1, 0.53	1.9, 1, 0.17
		Control	13.8	3.3	13.7	3.4			
STAI State	173	Forest	31.2	8.3	29.9	6.9	37.6, 1, <0.001	17.2, 1, <0.001	0.06, 1, 0.81
		Control	34.5	7.2	33.3	6.7			

df, degrees of freedom; SD, standard deviation; STAI, State–Trait Anxiety Inventory.
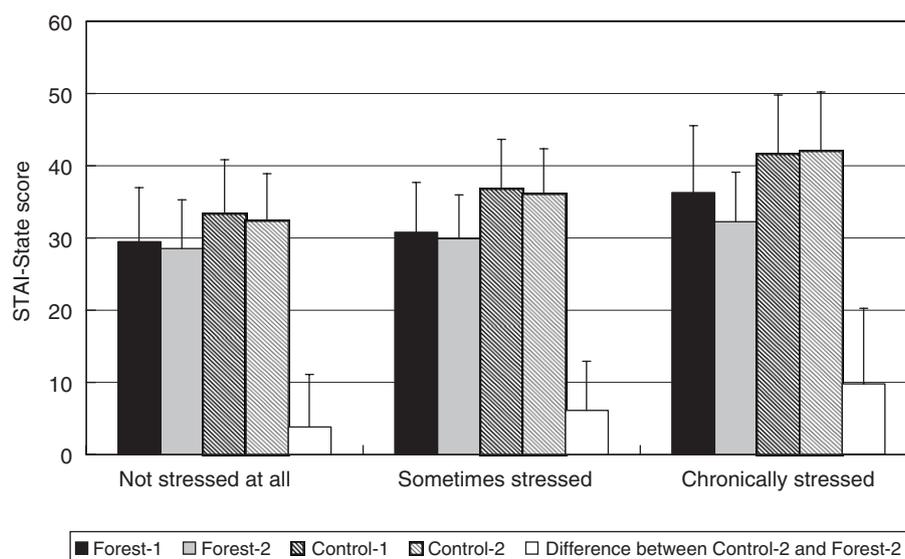
Figure 1 Mean State-Trait Anxiety Inventory A-State scores for each general stress subgroup on the forest and control days. Lines indicate standard deviations. The more stressed the participants, the more beneficial the effects of shinrin-yoku.

conditions gaining more beneficial effects. A significant interaction between E and general health was observed for two outcomes (hostility and boredom). Moreover, no significant interaction between E, T and age, and E, T and sex was observed for any of the outcomes. However, significant interactions between E and age, and E sex was seen for four outcomes (depression, boredom, wellbeing and STAI-S) and five outcomes (hostility, friendliness, wellbeing, liveliness and STAI-S), respectively, with younger participants and women gaining more beneficial effects.

The results of the multiple regression analyses are shown in Table 3. General stress levels, age, sex and enjoyment of walking in forests were significantly related to four outcomes, two outcomes, three outcomes and one outcome, respectively.

Discussion

This study revealed that acute emotions are improved by participation in shinrin-yoku. Some cohort studies have reported that hostility, depression and anxiety are related to the risk of coronary heart diseases (CHD).[37–41] Moreover, while a positive emotional style has been shown to decrease the risk of common colds,[42] an absence of positive wellbeing has been related to mortality.[43] In this study, hostility and depression scores decreased significantly as a result of participation in shinrin-yoku compared with the control day, not only in

subgroups that did not exercise or who were unable to take part in their favourite activities, but also in those who did exercise and who were able to take part in their favourite activities. These findings suggest that improvements in hostility and depression on the forest day were not caused simply by exercise or the ability to take part in favourite activities, but rather by the forest environment. Miyazaki and Motohashi[31] reported that in Profile of Mood States, the score for depression-dejection decreased in five students as a result of shinrin-yoku, supporting the results of the present study.

Furthermore, in each subgroup, the environment had a significant main effect on most outcomes, with the forest environment being advantageous, particularly for positive emotions. These results show that participants experienced beneficial effects on simply reaching the entrance of the forest, although it was not concluded whether the effect was caused by the forest environment or by participants' experiences up until reaching the forest or during the first survey. For example, Ulrich[28] reported that viewing trees from a window in a hospital promoted patients' recovery after surgery, suggesting that a visual factor alone can affect human health. Therefore, one reason for the beneficial effects may be visual factors, i.e. simply seeing the green environment of the forest. Regardless, it is clear that emotions were improved during participants' time in the forest.

Since approximately 500 participants took part in this study, it was possible to evaluate the factors related to the magnitude of the shinrin-yoku

Table 3 Results of multiple regression analysis; independent variables are indicated.

	R	Independent variables	β	P
Hostility	0.16	General stress level		
		Chronically stressed/not stressed at all	0.92	0.08
		Sex		
		Women/men	0.42	0.02
Depression	0.26	General stress level		
		Chronically stressed/not stressed at all	1.9	<0.001
		General stress level		
		Sometimes stressed/not stressed at all	0.97	<0.001
		Ability to take part in favourite activities on the control day		
		Able to/unable to	−0.6	0.008
Boredom	0.35	Ability to take part in favourite activities on the control day		
		Able to/unable to	−1.3	<0.001
		General stress level		
		Chronically stressed/not stressed at all	2.0	<0.001
		Age	−0.05	0.001
Friendliness	0.17	Ability to take part in favourite activities on the control day		
		Able to/unable to	1.0	<0.001
Wellbeing	0.22	Ability to take part in favourite activities on the control day		
		Able to/unable to	0.95	0.004
		Age	0.04	0.01
		Enjoyment of walking in forests		
		No preference/like	2.1	0.01
Liveliness	0.33	Ability to take part in favourite activities on the control day		
		Able to/unable to	1.5	<0.001
		Degree of physical exercise on the control day		
		Exercised/did not exercise	1.3	<0.001
		Sex		
		Women/men	−0.7	0.03
STAI State	0.37	Ability to take part in favourite activities on the control day		
		Able to/unable to	−2.8	<0.001
		Degree of physical exercise on the control day		
		Exercised/did not exercise	−2.3	0.001
		General stress level		
		Chronically stressed/not stressed at all	4.8	<0.001
		Sex		
		Women/men	1.6	0.01
		General stress level		
		Sometimes stressed/not stressed at all	1.7	0.02

STAI, State-Trait Anxiety Inventory.

effects. The conditions of the forest visit (e.g. duration of stay, etc.) had virtually no relationship with the magnitude of effects. It has been reported previously that the psychological effects of shinrin-yoku did not differ significantly between five different types of forest, although they were significantly different when compared with the effects achieved from visiting non-forested areas.[47] These findings suggest that no specific method and/or type of forest are required to gain beneficial psychological effects. For example, as the duration of stay in the forest did not affect the outcomes and since beneficial effects were observed on simply reaching the forest, it can be suggested that positive effects will be observed even after a short forest walk.

Despite the above, this study revealed that stress levels affect the magnitude of the psychological effects, with those feeling chronically stressed gaining more beneficial effects. Since chronically stressed individuals are classified as high risk with regard to various diseases,[48] shinrin-yoku may contribute to disease prevention. Some other relaxation intervention and stress management

programmes require specific techniques and certain skills.[12] Forest walking, on the other hand, has no specific requirements and anyone can take part.

The authors believe that forest environments may contribute to the maintenance of health and wellbeing (e.g. by reducing hostility and depression which are risk factors for CHD, or by improving overall emotions, particularly among populations with poor mental health). Accordingly, forest environments can be viewed as a therapeutic landscape, possibly grouped in the same category as scenic beauty.[24] However, the results of this study did not allow determination of whether the effects were due to the visual factors of scenic beauty alone or more complex factors. Further studies regarding why forest environments are effective in maintaining health and wellbeing are required.

However, a limitation of this study was that selection bias probably existed with regard to the participants. As more than 95% of participants expressed a liking for forest walks, it is unlikely that this was a representative sample of the general population.

In conclusion, walking and/or staying in the forest reduced hostility and depression, which are risk factors for CHD. These effects were not caused by exercise or being able to take part in favourite activities, but were due to the forest environment. Furthermore, a positive effect was reported for most emotions simply on reaching the forest. The efficacy of shinrin-yoku was particularly notable among those who were stressed; i.e. the high-risk population. This suggests that forest environments have a beneficial effect on mental health. Therefore, shinrin-yoku may be employed as a stress reduction method, and forest environments are considered to be therapeutic landscapes.

As an acute psychological effect was revealed, customary shinrin-yoku may help to decrease the risk of psychosocial stress-related diseases. Therefore, further research on how shinrin-yoku and forest environments contribute to health promotion is warranted.

Acknowledgements

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