Analysis of Electroencephalogram and Electrocardiogram Changes in Adults in National Healing Forests Environment

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ABSTRACT

This study analyzed the changes in Electroencephalogram(EEG) and Electrocardiogram(ECG) depending on the healing environment in order to find a way to improve the forest healing program based on the healing environment in response to the demand for qualitative improvement of the program since the program is a charged service. This study selected eight sites running forest healing programs at four national healing forests (i.e., Saneum, Cheongtaesan, Daegwanryeng, and Jangseong) - two routes per national healing forest - considering forest environments. This study chose NUMBER standard sampling plots (20×20m) and measured three atmospheric environment items, seven physical environment items, two soil environment items, and eight vegetation environment items including forest sound and anion at each plot to evaluate physiological changes in it. EEG and ECG, which have been widely used in forest healing evaluation, were utilized as criteria. Seventy three subjects were selected with taking the age, drug, caffeine, smoking, and the time of last meal into consideration. As a result, EEG changes were correlated with three atmospheric environment items, six physical environment items, one soil environment item, and two vegetation environment items. ECG changes were significantly correlated with two atmospheric environment items, six physical environment items, two soil environment items, and two vegetation environment items ($p < .05$). It is expected that 11 environmental factors such as temperature, density, and altitude affecting EEG (e.g., alpha balance and gamma balance) and ECG (e.g., HRV mean) could be used as effective tools in developing more differentiated programs for improving healing effects.

Keywords: ECG, EEG, forest environment, forest healing, forest therapy

Introduction

The advancement of industry has increased material wealth and improved the standard of living for people in modern society, but environmental pollution and rapidly changing environmental and social conditions have caused severe stress, having a bad impact on health (Kim, 2015). Under this stress, the improved standard of living has increased people's interest in the improved health and quality of life, and concepts such as well-being, wellness and healing have been created. Related industries have been converged with a variety of fields, expanding their market size (Cha, 2017). Well-being, wellness and healing start to be recognized as a concept of welfare at a societal level beyond personal needs (Kwon, 2014). Against this backdrop, the Korea Forest Service legislated to promote 'forest healing' through policies by utilizing forests that account for 64% of the national territory as a space for healing (Lee, 2016).

Received: September 24, 2018, **Revised:** October 12, 2018, **Accepted:** November 19, 2018

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Since the Korea Forest Service introduced the forest healing policy, Saneum Healing Forest was opened in 2010 as the first healing forest, and, as of now, there are 15 healing forests for short-period experiences, and one national forest healing center for mid and long-period experiences across the country (KFS, 2018). The Korea Forest Service is planning to additionally open and operate 31 healing forests and 1 forest healing center by 2020 (NIFoS, 2017). In addition, the number of users of forest healing programs has continuously increased from about 30,000 in 2012 to 120,000 in 2016, as the number of healing forests has increased (KFS, 2017).

As spaces available for forest healing have been expanded, and the demand for forest healing has increased, the necessity for quality forest healing programs has also increased. Those forest healing programs have been provided free of charge, but they have to be charged under Article 23 of the Forest Welfare Promotion Act, which raises the necessity for measures to improve the quality of forest healing programs. As one pillar of the plan for developing and improving forest healing programs, 102 unit activities included in the forest healing programs that are currently operated by healing forests by 2016 or presented in the master plan for creating healing forests were collected and their content was analyzed. The share of programs for special population, winter programs and everyday programs was low, while applied therapies or locations were mostly concentrated in psychotherapy and paths through forests or indoor. For this reason, it was concluded that programs for special population need to be strengthened, and that various places such as paths through forests, spaces within forests (spaces for meditation), water spaces, the geographical features of forests and healing facilities need to be utilized in order to actively apply phytotherapy, climatotherapy and hydrotherapy that have been less utilized (NIFoS, 2017).

To develop better quality forest healing programs, it is necessary to review environmental used for forest healing programs and healing effects when utilizing spaces for forest healing from various aspects. Since places for forest healing programs include various environments and forest healing factors, the effects of forest healing can be further promoted, and specialized forest healing programs can be developed more effectively by reviewing the relations between forest environment and healing effects from various angles.

However, earlier studies on improvement in forest healing programs and the evaluation of their effects mostly focused on the satisfaction and preference of forest healing facilities and programs (Y.H. Kim et al., 2014; Kweon and Kwon, 2014; Kim et al., 2015; Kweon, 2015; Kim, 2016) and on forest healing programs and subjects, viewing forests only with the concept of location (Jung et al., 2014; Kim and Park, 2016; Park, 2014). Those on the healing effects of programs depending on forest environmental elements mostly focused on a single environmental element (Kim et al., 2002; Shin et al., 2010; Joung et al., 2013; Song et al., 2015). Therefore, once studies are actively conducted on forest environmental elements and healing effects in actual forest environments where programs are performed, it will be possible to develop multiple differentiated programs that reflect the environmental characteristics of each region and to increase the healing effects of forests by utilizing forest environments more actively. To provide a base for this, this study formulated the following hypothesis based the results of earlier studies on a single environment: ‘the therapeutic effects of forests differ depending on the environment of forests.’ The forest environmental elements that can increase the healing effects of forests were suggested.

Research Methods

Target Sites

Target sites in this study were selected after formulating sub-hypotheses of the main hypothesis considering environmental elements that affect forest healing, and the sub-hypotheses were formulated as follows. First, healing effects differ depending on the type of trees. Second, healing effects differ depending on the type of low vegetation. Third, healing

effects differ depending on the existence of water systems. Fourth, healing effects differ depending on the density of forest trees. Based on these sub-hypotheses, two routes that provide forest healing programs in four national healing forests (Saneum, Cheongtaesan, Daegwanryeng, Jangseong) were selected, and target sites for this experiment were selected within the forest routes. In addition, to minimize the influence of the movement of subjects, final target sites were selected considering the distance from the starting point and the movement of subjects. Along the two selected routes, a total of 4 points including the starting, mid and end points, and each target site were selected, and a quadrat was placed at each point for a vegetation survey (standard sampling plots (20×20m)). The characteristics of each selected point in healing forests were as follows (Table 1 and Figure 1): At Point A in Saneum Healing Forest, coniferous trees dominated by *Pinus koraiensis* and low vegetation were observed. At Point B in Saneum Healing Forest, broadleaf trees dominated by *Quercus serrata* and water system were observed. At Point C in Cheongtaesan Healing Forest, broadleaf trees dominated by *Betula platyphylla* were observed. At Point D in Cheongtaesan Healing Forest, coniferous trees dominated by *Quercus mongolica* were observed. At Point E in Daegwanryeng Healing Forest, coniferous trees dominated by *Pinus koraiensis* and landscape views were observed. At Point F in Daegwanryeng Healing Forest, coniferous trees dominated by *Pinus koraiensis* were observed. At Point G in Jangseong Healing Forest, coniferous trees dominated by *Chamaecyparis obtusa* were observed. At Point H in Jangseong Healing Forest, mixed forests dominated by *Larix kaempferi* were observed.

Table 1. Status and forest healing factor measurements of test site

Site	Space			Vegetation survey							Microclimate· Forest healing factor				
	Route length (m)	Range (m)	Relative height (m)	Dominant species	Cover degree(%)				Ave -rage tree height (m)	Ave -rage DBH ^z (cm)	Degree of crown closure (%)	Temp. ^y (°C)	Humid. ^x (%)	Anion (ea/cm ³)	Sound of forest (dB)
					Tree	Arbore- scent	Shrub	Herb							
A	483	250	51 (300-351)	<i>Pinus koraiensis</i>	90	5	80	10	11	24	74.6	20.2	56.2	1,021.7	35.5
B	312	112	27 (285-312)	<i>Quercus serrata</i>	95	30	65	35	17	28	78.1	19.7	59.0	1,591.4	62.2
C	448	304	42 (888-930)	<i>Betula platyphylla</i>	85	90	10	65	16	24	90.1	17.6	79.4	55.6	41.9
D	917	552	59 (820-879)	<i>Quercus mongolica</i>	95	30	50	90	18	22	87.4	19.2	74.0	393.0	41.3
E	661	645	34 (243-277)	<i>Pinus densiflora</i>	90	-	50	90	22	56	73.7	24.9	83.3	509.4	50.5
F	826	570	123 (259-382)	<i>Pinus densiflora</i>	90	80	50	45	12	42	79.7	23.6	88.0	692.0	39.7
G	492	115	25 (377-402)	<i>Chamaec-yp aris obtusa</i>	90	20	10	5	25	30	76.6	22.9	69.5	401.1	48.9
H	500	200	52 (400-452)	<i>Larix kaempferi</i>	80	85	50	95	14	22	78.1	22.5	71.7	502.0	38.9

Note. See Figure 1 for the location of test site.

^zDBH = Diameter at breast height.

^yAverage temperature for ECG and EEG measurements.

^xAverage humidity for ECG and EEG measurements.

Figure 1. Satellite maps of test sites in healing forests for ECG and EEG measurements.

To identify healing effects depending on the type of trees, coniferous, broadleaf and mixed forests were selected, and they were also selected considering the existence of each environmental factor to identify healing effects depending on the existence of low vegetation and water systems. The density of forest trees was also considered.

Measuring Tools and Devices

Electrocardiogram (ECG)

Electrocardiogram (ECG) is the process of measuring electrical signals generated by the activity of the heart using

electrodes placed over the skin (Jeon et al., 2009). Compared to visualized devices, ECG cannot directly observe the activity of the heart, but can detect electrical changes that are undetectable with those visualized devices, having been widely used in clinical settings (Ryea, 2011). Heart rate variability (HRV) can be identified by measuring ECG, and interactions between the sympathetic and parasympathetic nerves that control the function of the cardiovascular system can be examined by measuring changes in heart rate. For this reason, HRV has been widely used in studies on the autonomic nervous system (Choi and Rho, 2004). Physical and psychological stress can be assessed by measuring HRV. Emotional conditions such as depression, panic disorder, anxiety and fear and stress factors mostly reduce the activity of parasympathetic nerves, affecting the function of autonomic nerves (Choi and Rho, 2004). Against this backdrop, this study measured the ECG of subjects to obtain HRV mean, SDNN and LF/HF ratio. HRV mean values show changes in the autonomic nervous system, and SDNN show resistance to stress. Balance in the autonomic nervous system can be also assessed through LF/HF ratio.

Electroencephalogram (EEG)

Electroencephalogram (EEG) is the process of measuring electrical signals generated by the electrical activity of the brain in a non-invasive way using electrodes placed over the skin (H.S. Kim et al., 2014). These electrical signals reflect the synaptic potential of the nerve cells of the cerebral cortex that plays a key role in sensation and perception, motor skills, thought, imagination and language (Seo et al., 2007). There are 4 types of brain waves: Delta (δ) waves are very slow and irregular, and are mostly observed during sleep, and theta (θ) waves are slow and are produced when pleasant and relaxed feelings and extreme arousal are combined, for instance between arousal and sleep or in a state of meditation. Alpha (α) waves have a relatively slow frequency and are observed in a state of relaxation at relatively slow frequency. Alpha waves are not observed when experiencing anxiety or stress, and thus are known to be related to a pleasant state of mind. Beta (β) waves have a rapid frequency, and are mostly observed in a state of waking, thinking and doing activities (Seo et al., 2007). Since brain waves contain a massive amount of information on the activity of the brain, information on mental activities and emotional states can be easily obtained from them, and thus they have been widely used in studies (Seo, 2006). In this study, after measuring EEG, the following values were measured using an EEG analysis system, called BIOS CARE (BIOBRAIN, Daejeon, Korea): delta, theta, alpha and beta waves, the peak of alpha waves, concentration, arousal, alpha balance and gamma balance. Delta waves are mostly observed in a completely relaxed state, but they are also high during eye movements. Theta waves are observed during arousal in a twilight state when having an idea or an inspiration. Alpha waves basically reflect stable conditions, and are very closely related to visual areas. Beta waves are generated in a state of arousal, doing activities, and, in particular, cognitive activities, and they are actively produced in a state of stress. A large amount of gamma waves are produced in a state of anxiety, excitement or severe stress, and they are also produced when intensively concentrating on something. The peak of alpha waves is used to assess the activity of the brain, and, when the value is within the normal range, the activity of the brain is normal. Concentration shows the level of concentrating on something, and arousal shows the level of emotional arousal. Those with a high tendency of depression show a low level of arousal. In addition, alpha balance and gamma balance are measured to identify asymmetric phenomena in the frontal lobes and to assess the tendency of depression. The low activity of the left frontal lobe indicates lack of positive emotions and a high tendency of depression. The high activity of the right frontal lobe is related to negative emotions such as evasion, indicating a high tendency of depression.

Measuring Devices

(1) Devices for Measuring Biosignals

Electroencephalogram (EEG) and electrocardiogram (ECG) were measured using BIOS-S3 (BIOBRAIN, Daejeon,

Korea) (Figure 2). BIOS-S3 measures four biosignals including EEG, ECG, EMG (electromyogram) and electro oculogram. These biosignals can be measured through four channels at the same time in a non-invasive way. Using BIOS-S3, brain waves and heart rate variability (HRV) were measured, and the measured data were converted into numerical values using a program called BIOS CARE (BIOBRAIN, Daejeon, Korea).

(2) Devices for Measuring Forest Environmental Elements

Anions were measured using COM-3200PRO and COM-3800 of COM System during measuring atmospheric environmental conditions, and temperature and humidity were measured using U23 PRO Series of Onset Computer. Sounds in forests were measured using EXTECH 407764 of EXTECH (Figure 3). The following data were obtained through surveys on the spatial information and natural environment: vegetation in target sites (trees, sub-trees, shrubs, herbs, dominant species, tree species, tree height, age class), the physical characteristics of routes (altitude, range, relative height, inclination, crown density, slope direction, density) and soil data (litter layer depth, soil hardness).

Measuring Methods and Subjects

Measuring Methods

A pre-survey and pre-test were carried out at a health center in each healing forest, and, after that, subjects moved to the selected sites for measurement mentioned above. Measurement was conducted at two points selected along each route where forest healing programs were provided in four healing forests (Saneum, Cheongtaesan, Daegwanryong, Jangseong) considering environmental factors and distance. Those who finished the pre-test were divided into two groups, and one

Figure 2. BIOS-S3.

Picture of instrument
Name	COM-3200PRO	COM-3800	U23 pro	EXTECH 407764

Figure 3. The instruments for measuring forest environmental factors.

group moved to one of the two points and the other group to the other point. After measurement, they took turns in order to minimize the effect of the first point they visited on the measured results. Measurement was conducted after taking a 10-min break in order to minimize the effect of movement to the selected point on the measured results. According to the standardized duration for the short-term analysis of heart rate variability (HRV), measurement was carried out for 5 minutes (Malik et al., 1996; Choi and Rho, 2004; Kim et al., 2006). Measurement was conducted a total of three times: one as a pre-test at a health center and one at each of the two selected points (Figure 4).

Brain waves were measured with electrodes placed on the forehead above the left eyebrow (FP1) and the right eyebrow (FP2), behind the left ear (GND), and the left ear (REF) according to the International Electrode System. HRV was measured with electrodes placed on the left wrist (P) and the right wrist (N). Atmospheric environmental conditions were measured simultaneously while the biosignals of subjects were measured in order to collect environmental data (temperature and humidity, anions, sounds in forests) during measuring the biosignals. In addition, posture, food ingestion, medication, accessories, mobile phones, etc. were controlled to prevent them from affecting the measured results of brain waves and HRV. All the measuring devices were placed behind subjects to prevent any visual effect they might cause.

Subjects

Subjects in this study were selected among those who booked to visit or worked at each healing forest. Healthy adults in their 20s–40s who did not take any medication that might affect biosignals were selected among them. They were informed in advance not to take any favorite food or meals that might affect their biosignals on the day of measurement. Their age was limited to the early 40s or younger to minimize any effect caused by age difference, and anyone who might affect the measurement of biosignals was excluded through a pre-survey questionnaire. The questionnaire was composed of a total of eight questions as follows: two questions on their demographic characteristics, one question on the time of movement to determine the length of break for relaxation, two questions on diagnosed diseases and drugs, and three questions on food ingestion that might affect measurement (Table 2).

Figure 4. Experimental design.

Table 2. Survey categories before measurement of ECG and EEG

Category	Subcategory	Number
Sociodemographic characteristic	Gender, date of birth	2
Transit time	Transit time	1
Disease and drug	Cardiovascular disorders, encephalopathy and medication being administered	2
Ingestion	Food eaten within 2 hours (coffee, green tea, black tea, soda, chocolate, tonics, energy drink), meal, smoke	3
Total		8

Table 3. Subjects characteristics by test site for ECG and EEG measurements

Test site		A	B	C	D	E	F	G	H
Gender	Male	6(46.2)	6(46.2)	13(65.0)	13(65.0)	9(45.0)	9(45.0)	15(75.0)	15(75.0)
	Female	7(53.8)	7(53.8)	7(35.0)	7(35.0)	11(55.0)	11(55.0)	5(25.0)	5(25.0)
Age	20s	5(38.5)	5(38.5)	12(60.0)	12(60.0)	18(90.0)	18(90.0)	5(25.0)	5(25.0)
	30s	8(61.5)	8(61.5)	8(40.0)	8(40.0)	1(5.0)	1(5.0)	7(35.0)	7(35.0)
	40s	-	-	-	-	1(5.0)	1(5.0)	8(40.0)	8(40.0)

Note. Values are frequency(percent). See Figure 1 for the location of test site.

The ECG and EEG of subjects were measured at 3 points including pre-test in each of the four selected healing forests, and 20 subjects for each healing forest were tested. A total of 73 subjects were tested three times, and thus 219 samples were collected. Detailed information on subjects for each target site was as shown in Table 1 and Table 3.

Analysis Methods

The measured data of biosignals and forest environmental elements were processed and analyzed using SPSS v.20. Data between points and healing effects depending on forest environmental elements were compared using ANOVA and independent T-test. The correlation between forest environmental elements and healing effects was analyzed, and the statistical significance level of this study was $p < .05$.

Results and Discussion

Measured Results

Measured Results of Target Points

Variation analysis was performed between target points in healing forests, and the results showed that alpha and gamma balance and HRV mean showed a statistically significant difference. Alpha and gamma balance are measured to identify asymmetric phenomenons in the frontal lobes. The higher alpha balance, the higher the tendency of depression. The higher gamma balance, the higher negative emotions such as evasion. Alpha and gamma balance was higher at Points C, D, E and F than other points. HRV mean indicates changes in the autonomic nervous system. Healthy adults have a slow pulse of 50 or lower when they feel fatigued, and a frequent pulse of 100 or higher when they are under stress or feel anxious. HRV

Table 4. ECG and EEG measurement results by test site

Site	Delta	Alpha	Theta	Beta	Alpha peak	Concentration	Arousal	Alpha balance	Gamma balance	HRV mean	SDNN	LF/HF
A	49.3	8.6	32.3	9.6	8.5	0.5	0.4	-0.0346	-0.0731	74.9	79.7	3.2
B	47.8	9.0	30.0	13.1	9.0	0.8	0.6	0.0069	-0.0596	74.1	56.5	1.7
C	48.5	9.3	31.3	10.9	8.60	0.51	0.44	0.1380	0.0965	72.8	54.1	1.5
D	49.5	8.8	29.5	11.9	8.66	0.55	0.48	0.1640	0.1165	70.3	84.7	1.6
E	46.0	11.2	31.8	11.9	8.5	0.5	0.4	0.1670	0.0765	88.7	47.4	2.1
F	44.4	11.0	30.7	12.7	8.5	0.5	0.4	0.1860	0.0970	92.8	51.0	4.2
G	48.5	8.6	31.9	11.0	8.4	0.6	0.5	0.0000	0.0270	67.0	68.0	3.8
H	46.7	9.6	31.9	11.8	8.4	0.6	0.5	0.0085	0.0260	70.5	72.5	1.9
<i>p</i>	.051	.070	.080	.458	.379	.375	.923	.000*	.001*	.000*	.657	.269

Note. See Figure 1 for the location of test site.

*Significant at $p < .05$ by one way ANOVA.

mean was the lowest at Point G and the highest at Point F.

Healing Effects of Forest Environmental Elements

Alpha and gamma balance and HRV mean showed a statistically significant difference in the results of comparing the entire points depending on forest environmental elements, and their differences were analyzed to verify the hypotheses of this study. Differences depending on the hypothesis of this study were analyzed, and statistically significant differences were observed in alpha and gamma balance, and HRV mean under all the hypotheses except the existence of water systems. In addition, all the results of the homogeneity test were higher than .05, the significance test of this study, indicating that variation analysis between groups can be performed on these samples.

The first sub-hypothesis was ‘healing effects differ depending on the type of trees,’ and differences depending on the type of trees were analyzed. There were statistically significant differences in alpha and gamma balance, and HRV mean (Table 5). The significance probability of alpha balance and HRV mean was .000, and that of gamma balance was .002, showing average differences. Specifically, there was the highest difference in alpha balance between *Pinus densiflora* and *Pinus Koraiensis*, and in HRV mean between *Pinus densiflora* and *Chamaecyparis obtusa*.

The second sub-hypothesis was ‘healing effects differ depending on the type of low vegetation’ and differences depending on the type of low vegetation were analyzed. There were statistically significant differences in alpha and gamma balance, and HRV mean (Table 6). The significance probability of alpha and gamma balance and HRV mean was .000, showing average differences.

The third sub-hypothesis was ‘healing effects differ depending on the existence of water systems,’ and differences depending on the existence of water systems were analyzed. There were statistically significant differences in alpha balance (Table 7). The significance probability of alpha balance was .000, showing average differences.

The fourth sub-hypothesis was ‘healing effects differ depending on the density of forest trees,’ and differences depending on the density of forest trees (tree/ha) were analyzed. There were statistically significant differences in alpha and gamma balance and HRV mean (Table 8). The significance probability of alpha balance and HRV mean was .000, and that of gamma balance was .003, showing average differences. Specifically, 469 tree/ha and 906 tree/ha showed the highest difference in alpha balance, and 469 tree/ha and 608 tree/ha showed the highest difference in HRV mean.

Table 5. Result of one way ANOVA: Alpha & gamma balance, HRV mean difference according to species

	Factor	M	SD	F / p-value	Posteriori tests
Alpha balance	(a) ^z <i>P. koraiensis</i>	0.02555	0.00709	31.496/.000*	b > d b, c, d > a, e, f, g (Scheffe)
	(b) <i>P. densiflora</i>	0.07411	0.01172		
	(c) <i>B. platyphylla</i>	0.06320	0.01413		
	(d) <i>Q. mongolica</i>	0.05951	0.01331		
	(e) <i>C. obtusa</i>	0.06617	0.01480		
	(f) <i>L. kaempferi</i>	0.04428	0.00990		
	(g) <i>Q. serrata</i>	0.05226	0.01449		
Gamma balance	(a) <i>P. koraiensis</i>	0.05310	0.01473	3.758/.002*	-
	(b) <i>P. densiflora</i>	0.05256	0.00831		
	(c) <i>B. platyphylla</i>	0.06637	0.01484		
	(d) <i>Q. mongolica</i>	0.08663	0.01937		
	(e) <i>C. obtusa</i>	0.09698	0.02169		
	(f) <i>L. kaempferi</i>	0.07702	0.01722		
	(g) <i>Q. serrata</i>	0.11415	0.03166		
HRVm	(a) <i>P. koraiensis</i>	74.9231	12.09278	19.249/.000*	b > a, c, d, e, f, g (Scheffe)
	(b) <i>P. densiflora</i>	90.7875	11.14488		
	(c) <i>B. platyphylla</i>	72.7650	10.63818		
	(d) <i>Q. mongolica</i>	70.3100	10.20113		
	(e) <i>C. obtusa</i>	67.0200	7.22558		
	(f) <i>L. kaempferi</i>	70.4650	7.58088		
	(g) <i>Q. serrata</i>	74.1308	10.95707		

^zMark for posteriori tests.*Significant at $p < .05$ by one way ANOVA.**Table 6.** Result of independent two-sample t-test: Alpha & gamma balance, HRV mean difference according to low vegetation

	Factor	M	SD	t	p
Alpha balance	None	0.1860	0.08344	7.027	.000*
	Exist	0.0177	0.02555		
Gamma balance	None	0.0970	0.04207	4.171	.000*
	Exist	0.0277	0.05310		
HRVm	None	92.8300	12.30157	4.113	.000*
	Exist	74.9231	12.09278		

*Significant at $p < .05$, $t \geq 1.96$ by independent two-sample t-test.**Table 7.** Result of independent two-sample t-test: Alpha balance difference according to drainage system

	Factor	M	SD	t	p
Alpha balance	None	0.1645	0.05951	6.569	.000*
	Exist	0.0315	0.05226		

*Significant at $p < .05$, $t \geq 1.96$ by independent two-sample t-test.

Table 8. Result of one way ANOVA: Alpha & gamma balance, HRV mean difference according to density

	Factor		M	SD	F / <i>p</i> -value	Posteriori tests
Alpha balance	(a) ^z	350	0.1730	0.06498	26.955/.000*	a, b, d, f > c, e, g, h (Scheffe)
	(b)	469	0.1860	0.08344		
	(c)	492	0.0315	0.05226		
	(d)	575	0.1505	0.06320		
	(e)	608	0.0400	0.06617		
	(f)	667	0.1645	0.05951		
	(g)	669	0.0285	0.04428		
	(h)	906	0.0177	0.02555		
Gamma balance	(a)	350	0.0850	0.06186	3.238/.003*	-
	(b)	469	0.0970	0.04207		
	(c)	492	0.0615	0.11415		
	(d)	575	0.1055	0.06637		
	(e)	608	0.0545	0.09698		
	(f)	667	0.1190	0.08663		
	(g)	669	0.0395	0.07702		
	(h)	906	0.0277	0.05310		
HRV _m	(a)	350	88.7450	9.73872	16.808/.000*	a, b > c, d, e, f, g, h (Scheffe)
	(b)	469	92.8300	12.30157		
	(c)	492	74.1308	10.95707		
	(d)	575	72.7650	10.63818		
	(e)	608	67.0200	7.22558		
	(f)	667	70.3100	10.20113		
	(g)	669	70.4650	7.58088		
	(h)	906	74.9231	12.09278		

^zMark for posteriori tests.*Significant at $p < .05$ by one way ANOVA.

Forest Environmental Elements and Healing Effects

Effect of Forest Environmental Elements on HRV Mean (Physical)

HRV mean (physical) showed the positive correlation with temperature, humidity, range, relative height, age class and inclination, and the negative correlation with crown density, tree species, altitude, density and litter layer depth (Table 9).

Effect of Forest Environmental Elements on α -balance and γ -balance (Emotional)

Alpha balance showed the positive correlation with temperature, humidity, range, relative height, crown density, altitude, age groups, slope direction and soil hardness, and the negative correlation with anion, tree species, and density. Gamma balance showed the positive correlation with distance, crown density, altitude, age class, slope direction and soil hardness. and the negative correlation with density (Table 9).

The main hypothesis of this study, ‘the therapeutic effects of forests differ depending on the environment of forests,’ was tested, and changes in the body caused by different forest environmental conditions were observed. The analysis

Table 9. Result of correlation analysis between forest environmental factors and biosignal (ECG and EEG)

	Alpha B	Gamma B	HRVm	Temperature	Humidity	Sound of forest	Anion	Range	Relative height	Degree of crown closure	Species	Elevation	Age-class	Slope	Slope Direction Line	Density	Depth of litter layer	Soil hardness
Alpha B	1																	
Gamma B	.220*	1																
HRVm	-	-	1															
Temperature	.409**	.108	.514**	1														
Humidity	.357**	-.006	.268**	.320**	1													
Sound of forest	-.084	-.020	.015	.073	-.038	1												
Anion	-.365**	-.178	.050	-.011	-.575**	.395**	1											
Range	.677**	.256**	.492**	.693**	.293**	-.190*	-.303**	1										
Relative height	.371**	.123	.417**	.369**	.296**	-.490**	-.180	.503**	1									
Degree of crown closure	.343**	.269**	-.165*	-.378**	.014	-.260**	-.455**	.152	.174*	1								
Species	-.212*	-.029	-.345**	-.506**	-.007	-.118	-.094	-.325**	-.148	.434**	1							
Elevation	.279**	.242**	-.283**	-.441**	-.019	-.329**	-.578**	.098	.003	.952**	.403**	1						
Ageclass	.628**	.282**	.505**	.477**	.280**	.070	-.063	.692**	.678**	.358**	-.273**	.132	1					
Slope	.089	.009	.340**	.121	-.023	-.207*	.575**	.079	.799**	.038	-.198*	-.193*	.570**	1				
Slope Direction Line	.484**	.317**	.025	.027	.074	.094	-.179	.529**	.194*	.698**	.286**	.618**	.564**	-.073	1			
Density	-.437**	-.164*	-.432**	-.619**	-.513**	-.550**	.088	-.473**	-.082	.116	.257**	.256**	-.612**	.014	-.263**	1		
Depth of litter layer	.176*	.144	-.308**	-.211*	.387**	-.356**	-.851**	.026	-.093	.504**	.204*	.681**	-.186*	-.489**	.247**	.148	1	
Soil hardness	.529**	.255**	.293**	.409**	.135	.240**	-.182	.532**	.147	.161	-.750**	.142	.618**	.074	.329**	-.499*	.105	1
Tree height	.156	.054	.102	.181*	-.173*	.228**	.127	.398**	-.369**	.007	.254**	.010	.018	-.471**	.348**	-.257**	-.259**	-.096

*Significant at $p < .05$, ** $p < .01$ by correlation analysis.

results of selected points in healing forests showed that alpha and gamma balance, and HRV mean among the measured biosignals, showed statistically significant differences. Healing effects depending on the conditions of the sub-hypotheses including tree species, low vegetation, water systems and the density of forest trees also showed statistically significant differences.

Phytoncide therapy through forest experiences was reported to reduce the amount of cortisol that responds to stress, and to increase the resistance of alpha waves and the autonomic nervous system to stress (Lee and Lee, 2012). Differences in physiological and psychological healing effects (physical relaxation and stress reduction) were observed depending on the

type of therapy spaces through indoor horticultural therapy and repeated forest healing experiments (Park, 2014). Based on the results of these earlier studies, and those of this study, it can be said that forest environment affects forest healing effects. In addition, differences in healing effects depending on tree species, low vegetation, water systems and the density of forest trees in this study also coincide with the results of the following earlier studies. Differences in the sense of comfortability, space and closeness, orderliness and psychological recovery were observed depending on tree species and forest type (Kim, 2014), and there were differences in alpha waves and pulse rate within coniferous forests and broadleaf forests (Kim et al., 2002). Walking around a lake with a forest and enjoying its scenery resulted in physiological and psychological stability (Song et al., 2015), and there were differences in HRV when the stand density of *Pinus koraiensis* was 120% and 80% (Park et al., 2015).

In this study, there were 13 environmental factors that affected alpha and gamma balance related to depression and negative emotions as follows: temperature, humidity, anion, crown density, tree species, age class, density, range, relative height, altitude, slope direction, litter layer depth and soil hardness. There were also 13 environmental factors that affected HRV mean related to changes in the autonomous nervous system as follows: temperature, humidity, crown density, tree species, tree height, age class, density, range, relative height, altitude, slope, litter layer depth and soil hardness. The number of environmental factors that affected both alpha and gamma balance and HRV mean was 11 including temperature, humidity, crown density, tree species, age class, density, range, relative height, altitude, litter layer depth and soil hardness. Therefore, if environmental factors that affect the body are considered when designing a forest healing program, it will be possible to keep a balance between physical and emotional activities in the overall effects of the program, and to select program activity points where high physical and emotional effects can be obtained for the purpose of the program. Therefore, if a forest healing program is designed considering environmental factors that affect the body and the environmental characteristics of a certain point where the forest healing program is provided, it will be possible to develop more differentiated programs for each healing forest, and to develop various and more effective and quality forest healing programs.

Conclusion

In this study, changes in brain waves and heart rate variability (HRV) depending on forest healing environment were observed, which is expected to establish a foothold for clinical studies on the healing effects of forest environmental elements. It will also contribute to the active utilization of forest environmental elements in selecting locations and designing forest healing programs, and thus to qualitative improvements in forest healing programs through specialization and differentiation.

Meanwhile, there were some limitations in this study. First, elements were not completely independent and affected each other, and, to some extent, it is difficult to ignore autocorrelation issues. For instance, density, crown density and altitude affect temperature and humidity, and thus they cannot be recognized as a completely independent variable. In addition, data were not measured at a regular interval over time, but there are still autocorrelation issues. Therefore, it will be necessary to conduct follow-up studies considering correlations over time. Second, sounds in forests were measured in decibel (db) only, and the sources of the sounds were not analyzed. In this study, sounds in forests were not found to be an element that affected brain waves and HRV, but they were measured in decibel, which requires an additional analysis on the sources of sounds in forests. Third, healing effects depending on the existence of environmental elements were identified in this study, but there were not enough samples to distinguish the positiveness or negativeness of the healing effects. Therefore, it will be necessary to conduct additional surveys and analysis on the 11 environmental elements that

were found to affect the healing effects including, temperature, humidity, crown density, tree species, age class, density, range, relative height, altitude, litter layer depth and soil hardness. The utilization of these elements will further increase through these follow-up studies.

To design more specialized forest healing programs, it will be necessary to conduct more segmented and customized studies for environmental elements for the purpose of healing programs. The existing forest healing programs have mostly utilized forest environment as a place for forest healing. Field-oriented studies on the healing effects of forest environmental elements need to be continuously conducted to directly connect the elements to healing effects, and thus to clinically test the healing effects of forest environment. Once clinical studies on the healing effects of the environmental characteristics of healing forests are actively conducted, and forest environment is directly utilized as an healing element, forest healing will be recognized as a more specialized field.

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