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Research paper

Effect of inhalation of essential oil from *Inula helenium* L. root on electroencephalographic (EEG) activity of the human brain

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ABSTRACT

Introduction: In traditional systems of medicine, *Inula helenium* root is widely used for the management of various ailments. The present work investigates the effect of inhalation of essential oil from the root of *I. helenium* on electroencephalographic (EEG) activity of the human brain.

Methods: The effect of inhalation of *I. helenium* essential oil on EEG activity was evaluated by the measurement of the EEG power spectrum in 20 healthy participants. The EEG spectrum values were recorded using QEEG-8 system from 8 ground electrodes according to the International 10–20 System.

Results: The results showed that the inhalation of essential oil of *I. helenium* produced significant changes in the EEG power spectrum values. The reduction of absolute theta (all the regions except T3), beta (Fp1) and mid beta (P4) and relative theta (Fp1, Fp2, F3 and F4) waves were observed during the inhalation. Whereas, the ratio of SMR to theta (Fp1 and P4), SMR ~ mid beta to theta (Fp1) and spectral edge frequency 50% of alpha (P4) significantly increased during the inhalation of *I. helenium* essential oil.

Conclusion: The changes in EEG values due to the inhalation of essential oil of *I. helenium* root may enhance the alertness state of the brain and could be used for the treatment of psychophysiological disorders.

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1. Introduction

Historically essential oils from plants have been used widely to treat psychophysiological disorders [1]. It has been observed that fragrances from essential oils can influence the physical and mental conditions of human beings [2]. However, the efficacy of many plants has not been scientifically evaluated [3,4]. The psychological changes induced through the fragrance inhalation of essential oils are generally related to the modulation of olfactory nervous system. Through the olfactory system, the olfactory bulb receives the fragrance signals and provides input to other centers that modify neuronal activity [5,6]. Fragrances affect spontaneous brain activities and cognitive functions and these changes are estimated by electroencephalography (EEG) [7].

Inula helenium L. (Asteraceae) is a perennial herb native to Middle Asia and widely occurs in Asia, Europe and Northern America. The plant is used by traditional healers to treat various diseases such as asthma, bronchitis, cough, indigestion, urinary infections, and skin disorders [8]. The root of *I. helenium* mainly contains eudesmane-type sesquiterpene lactones (alantolactone and isoalantolactone) with various pharamacological properties such as antihelmintic, anti-inflammatory, and antimicrobial activity and the potential to induce detoxifying enzymes [8–10]. The sesquiterpene lactones from *I. helenium* exhibited cytotoxic and antiproliferative activities against human cancer cell lines [11,12]. However, there have been no studies on the effect of fragrance stimulation by the essential oil from *I. helenium* root. The aim of the present study was to investigate the effect of inhalation of essential oil from the root of *I. helenium* on EEG activity of human brain in normal healthy individuals.

2. Materials and methods

2.1. Plant material and extraction of essential oil

The root sample of *I. helenium* was purchased from BN Herb Inc., Pyeongchang, Republic of Korea during the month of August 2012. The essential oil of *I. helenium* root was isolated by steam

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Table 1
EEG power spectrum indicators used in this study.

S. No.	Analysis indicators	The full name of the EEG power spectrum indicators	Wavelength range (Hz)
1	AT	Absolute theta	4 ~ 8
2	AA	Absolute alpha	8 ~ 13
3	AB	Absolute beta	13 ~ 30
4	AG	Absolute gamma	30 ~ 50
5	ASA	Absolute slow alpha	8 ~ 11
6	AFA	Absolute fast alpha	11 ~ 13
7	ALB	Absolute low beta	12 ~ 15
8	AMB	Absolute mid beta	15 ~ 20
9	AHB	Absolute high beta	20 ~ 30
10	RT	Relative theta	(4 ~ 8)/(4 ~ 50)
11	RA	Relative alpha	(8 ~ 13)/(4 ~ 50)
12	RB	Relative beta	(13 ~ 30)/(4 ~ 50)
13	RG	Relative gamma	(30 ~ 50)/(4 ~ 50)
14	RSA	Relative slow alpha	(8 ~ 11)/(4 ~ 50)
15	RFA	Relative fast alpha	(11 ~ 13)/(4 ~ 50)
16	RLB	Relative low beta	(12 ~ 15)/(4 ~ 50)
17	RMB	Relative mid beta	(15 ~ 20)/(4 ~ 50)
18	RHB	Relative high beta	(20 ~ 30)/(4 ~ 50)
19	RST	Ratio of SMR to theta	(12 ~ 15)/(4 ~ 8)
20	RMT	Ratio of mid beta to theta	(15 ~ 20)/(4 ~ 8)
21	RSMT	Ratio of SMR ~ mid beta to theta	(12 ~ 20)/(4 ~ 8)
22	RAHB	Ratio of alpha to high beta	(8 ~ 13)/(20 ~ 30)
23	SEF50	Spectral edge frequency 50%	4 ~ 50
24	SEF60	Spectral edge frequency 90%	4 ~ 50
25	ASEF	Spectral edge frequency 50% of alpha	8 ~ 13

distillation technique (Hanil LabTech., Republic of Korea). The distillation was carried out for a period of 150 min (yield, 0.02% w/v).

2.2. Ethics

The study followed the Declaration of Helsinki on Biomedical Research Involving Human Subjects and was approved by the ethics committee from the Kangwon National University Hospital, Chuncheon, Republic of Korea.

2.3. Subjects

Twenty right-handed healthy volunteers (Students) from Department of Biological Environment, Kangwon National University (10 men and 10 women) aged 20–30 years participated in this study. None of the participants had olfactory diseases, physical or mental health problems, smoked or abused drugs. Informed consent was obtained from each subject before participation.

2.4. Experimental design

A single group pre-test and post-test experimental design was used in this study (20 subjects). A careful measurement was carried out before and during the inhalation of essential oil. Prior to experiment, the subjects were screened for an olfactory evaluation test by using the commercial perfumes. The subjects were told the purpose of the study was to determine the effect of inhalation of essential oil on EEG activity. After the EEG recordings, the participants were asked to give their preference and impression of the fragrance of *I. helenium* essential oil. Further, none of the participants indicated that they felt that the essential oil had affected them in any way.

2.5. EEG recordings

The EEGs were recorded using QEEG-8 system (LXE3208, LAXTHA Inc., Daejeon, Republic of Korea). The electrodes (silver/silver chloride) were placed on the scalp at left prefrontal (Fp1), right prefrontal (Fp2), left frontal (F3), right frontal (F4), left temporal (T3), right temporal (T4), left parietal (P3) and right parietal (P4) according to the International 10–20 System. All electrodes were referenced to the ipsilateral earlobe electrodes. The EEG sampling rate of the measured subjects was 256 Hz, filtered in the range of 0.5–50 Hz, and the readings were stored in a computer by the 12-bit AD conversion. The ECI electrode gel (Electro-gel^{TM}, Electro-Cap International Inc., Eaton, Ohio, USA) was applied into each electrode to connect with the surface of the scalp in order to drop the electric resistance of the scalp below 5 kΩ.

2.6. Odor administration

Essential oil of *I. helenium* root was used as the odor stimulus. The EEG measurement room was maintained with a constant temperature (23 °C) and humidity (50%). The subjects were instructed to sit quietly, close their eyes and to breathe normally during the measurement. The undiluted essential oil of *I. helenium* (10 μL) was spotted on the filter paper then placed about 3 cm in front of the subject's nose. The fragrance exposure was presented only once per subject. The EEG readings were recoded 45 s before and another 45 s during the inhalation. And the interval time between before and during the analysis was 3 min.

2.7. Data analysis

The mean power values [microvolt (μV)] were calculated for 25 EEG analysis indicators (Table 1). The t-mapping of EEG waves of brain was constructed by using Telescan software package (LXSMD61, LAXTHA Inc., Daejeon, Republic of Korea). The SPSS statistical package version 18 (SPSS, Inc., IL, USA) was used for data analysis on EEG activity before and during the exposure of essential oil by a paired *t*-test based on the EEG power spectrum values.

3. Results

The results of EEG changes and t-mapping of brain are presented in Table 2 and Fig. 1. The main characteristic smells of essential oil from the root of *I. helenium* are woody, balsamic and earthy. Out of 25 EEG indices, significant changes were observed in

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Table 2
Significant changes in EEG power spectrum values due to the inhalation of essential oil from *Inula helenium* roots.

EEG indices	Site	Before inhalation (μV)	During inhalation (μV)	*t*-test	*P* value*
Absolute theta	Fp1	16.911	12.599	3.164	0.005
	Fp2	15.099	11.055	2.628	0.017
	F3	20.881	16.610	2.393	0.027
	F4	20.751	16.258	2.577	0.018
	T4	6.884	5.720	3.488	0.002
	P3	18.250	15.593	2.746	0.013
	P4	15.760	12.950	3.510	0.002
Absolute beta	Fp1	9.471	8.517	2.341	0.030
Absolute mid beta	P4	5.262	4.055	2.807	0.011
Relative theta	Fp1	0.268	0.225	2.954	0.008
	Fp2	0.241	0.200	3.153	0.005
	F3	0.283	0.246	2.407	0.026
	F4	0.288	0.248	2.448	0.024
Ratio of SMR to theta	Fp1	0.204	0.250	−2.169	0.043
	P4	0.336	0.448	−2.165	0.043
Ratio of SMR ~ mid beta to theta	Fp1	0.483	0.600	−2.185	0.042
Spectral edge frequency 50% of alpha	P4	9.997	10.166	−2.216	0.039

Fp1: Left prefrontal, Fp2: Right prefrontal, F3: Left frontal, F4: Right frontal, T3: Left temporal. T4: Right temporal, P3: Left parietal, P4: Right parietal.
* Significant difference ($P < 0.05$).

7 indices during the inhalation of essential oil of *I. helenium* root. The reduction of absolute theta was observed in all the regions with the exception of left temporal region (T3). In addition, absolute beta (Fp1), absolute mid beta (P4) and relative theta (Fp1, Fp2, F3 and F4) activities decreased during the inhalation of essential oil than before inhalation. On the other hand, the values of ratio of sensorimotor rhythm (SMR) to theta (Fp1 and P4) and SMR ~ mid beta to theta (Fp1) were significantly increased. Further, the values of spectral edge frequency 50% of alpha spectrum significantly increased in the left parietal (P4) region during the inhalation of essential oil. The overall results indicate that the fragrance inhalation of *I. helenium* essential oil highly affected the left prefrontal region followed by right parietal than other regions.

4. Discussion

Recently, several studies have focused on the psychophysiological activities of fragrances from essential oils and their individual components. However, many of these studies were evaluated under *in vitro* in relation to mechanisms of action of psychoactive compounds and only few studies have been carried out to investigate their efficacy in humans [13]. The essential roles of aroma are creating a positive atmosphere by activating emotions, providing contextual clues, and supporting memory by neurochemical and neurobiological effects [14,15]. The EEG is an extensively used neurophysiological tool to exhibit the functions of human brain. In the present study, theta waves remarkably decreased in 7 out of 8 regions (except T3) when compared to other waves. The t-mapping clearly established the changes based on the EEG values (Fig. 1). The theta rhythm has been considered to sustain attention during performance of difficult task. Further, reduction in theta activity is highly associated with the memory formation [16,17]. The reduction of theta wave might be enhancing the attention state of brain.

The present study reveals that the absolute beta and absolute mid beta activities significantly decreased in the left prefrontal (Fp1) (from 9.471 to 8.517 μV) and right parietal (P4) (from 5.262 to 4.055 μV) regions, respectively. In general, the beta activity decreases during the drowsiness state and increases with a high alertness level [18]. However, the absolute theta [Fp1 ($P < 0.005$) and P4 ($P < 0.002$)] and relative theta also significantly decreased in the regions where beta wave decreased. In addition, Diego et al. [19] reported that the rosemary oil enhances the alertness state of brain by decreasing the frontal alpha and beta waves. Furthermore, the ratio of sensorimotor rhythm activities (SMR to theta and SMR ~ mid beta to theta) increased in left prefrontal (FP1) regions. Kober et al. [20] stated that the SMR activity (12–15 Hz) in the EEG is mainly associated with the states of physically relaxed and mentally focused.

Previously, several authors have reported that the inhalation of essential oils (lavender, rose and agar wood oils) and aromatic components produced positive psychological changes in the human brain [21,22]. From the results, the changes of EEG spectrums were mainly observed in the left prefrontal region when compared with other regions (Table 1 and Fig. 1). High-level cognitive functions have been localized to the prefrontal cortex. It is thought to be the most significant region for working memory [23]. The essential oil of *I. helenium* root was characterized by a relatively high amount of sesquiterpenoids (90.2%). The major components of the essential oil were isomeric eudesmane-type sesquiterpene lactones such as alantolactone (55.8%), isoalantolactone (26.1%), and diplophyllin (5.1%) [24]. These components might be responsible for the fragrance of essential oil of *I. helenium* root and its effects on brain function. The present study clearly indicates that the changes in theta and ratio of SMR values due to fragrance inhalation of essential oil of *I. helenium* may enhance the alertness state of the brain. To determine the exact psychophysiological effects of this essential oil on human brain, further studies are warranted in relation to the influences of gender, age and nostril differences on EEG activities.

The present study has some limitations. In the EEG recordings, the EEG readings were optimized many times due to the subjects' eye movement. In addition, there were more deviations in the EEG results among the individuals (20 subjects). In the present study, 100% essential oil was used as a fragrance stimulus, the result may be different when modify the concentration of the essential oil. Further, the EEG readings were recorded for short duration of time (30 s). Hence, it is still unknown whether this essential oil will show the same effect for long duration (>1 min) with more

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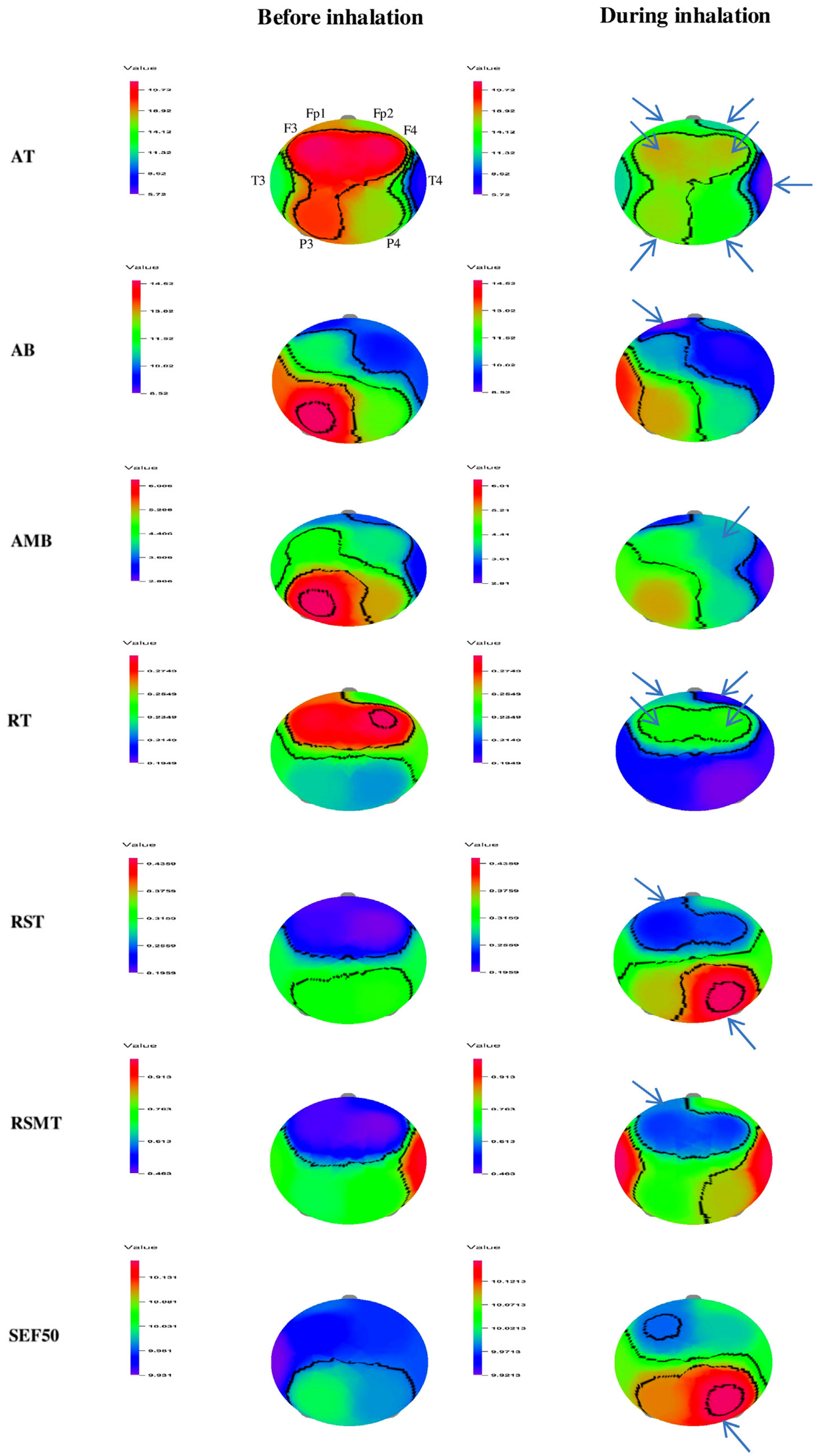

Fig. 1. The t-mapping of EEG changes before and during the inhalation of essential oil of *I. helenium* root. Fp1—left prefrontal, Fp2—right prefrontal, F3—left frontal, F4—right frontal, T3—left temporal, T4—right temporal, P3—left parietal, P4—right parietal. AT—absolute theta, AB—absolute beta, AMB—absolute mid-beta, RT—relative theta, RST—ratio of SMR to theta, RSMT—ratio of SMR-mid beta to theta, SEF50—spectral edge frequency 50% of alpha.

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participants. In the light of these limitations, the EEG recordings for long duration and different concentrations of essential oil with placebo control are needed prior to use this essential oil in the aromatherapy treatments.

5. Conclusion

The essential oil of *I. helenium* root appears to affect brain function by increasing alertness and concentration. Results of the present investigation suggest that the essential oil of *I. helenium* root may be used therapeutically with positive psychological effects.

Conflict of interest

The authors declare that they have no potential conflict of interest.

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