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Research Article

Clinical Study on Appetite-Control Effects and EEG Responses Using Natural Fragrances

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Abstract

We conducted a clinical investigation to confirm the effects of inhaling the natural grapefruit scent on appetite regulation and EEG changes. Among 32 female college students in their 20s who participated, six were excluded due to data collection errors. EEG measurements were taken using Neuroelectrics' Starstim 8, with electrodes placed at AF3, AF4, F3, F4, C3, C4, O1, and O2 per the international 10–20 system. Per our findings, inhaling the grapefruit scent led to higher PSD in the delta, theta, and alpha bands on the topographical map. Alpha waves increased at AF3, AF4, F3, and C4, indicating a stabilizing effect on EEG and stress relief due to grapefruit scent stimulation. Subjective stress evaluations revealed a statistically significant decrease in stress after inhaling the grapefruit scent compared with before, confirming the stress-relieving effect of the scent. Subjective appetite assessments revealed a statistically significant decrease in appetite among both normal weight and overweight participants, as well as overall among all subjects, indicating the appetite-suppressing effect of grapefruit scent stimulation. Therefore, in this study, we verified the stress-relieving and appetite-regulating effects of inhaling the natural grapefruit scent through objective EEG measurements and subjective evaluations of stress and appetite.

Keywords: Natural Fragrances; EEG; Stress; Neurocosmetics; Appetite Control

Introduction

In contemporary society, with the Westernization of beauty standards perpetuated by various mass media outlets, there is a strong societal inclination toward emphasizing excessive thinness among women in South Korea. Consequently, there is a general preference for slender body types among young Korean women. This societal trend has led to frequent attempts at dieting among many women in their 20s, including those within a healthy weight range. While it is advisable to pursue proper weight management practices such as regular exercise and balanced diet consumption, resorting to inappropriate methods such as fasting, starvation, or chemotherapy for weight control may result in ineffective weight management or even induce health issues such as nutritional imbalances, eating disorders, or binge eating.

According to previous studies, women tend to be more sensitive to perceptions of obesity than men. They often experience heightened self-awareness and stress regarding their body image, even when they are categorized as underweight or within a healthy weight range. This underscores the importance of addressing societal pressures and promoting realistic body image ideals to mitigate the adverse effects of distorted body image perceptions, which may cause significant psychological distress among women [2].

Previous research targeting college women reported that approximately 46.2% of underweight and 82.1% of normal-weight female college students were engaging in weight control behaviors. Moreover, Korean female university students had the highest weight loss attempt rate (77%) despite having the lowest average BMI (19.3 kg/m2). Additionally, neurotic binge eating disorder, which is characterized by inappropriate and repetitive compensatory behaviors such as vomiting, medication misuse, or fasting to suppress weight gain, is particularly prevalent among individuals in their 20s and 30s, with the prevalence being higher among women than among men. Those with binge eating tendencies are highly vulnerable to stress and tend to engage in binge eating as a coping mechanism to alleviate negative emotions.

The treatment of neurotic binge eating disorder typically involves medication; however, there is a growing interest in aroma inhalation therapy as a cost-effective and rapidly effective alternative. Currently, there is a dearth of research on appetite regulation using inhalation therapy, highlighting the importance of addressing stress-induced binge eating behaviors among college women and the issues of drug misuse resulting from inappropriate dieting. Thus, this study aims to investigate whether inhaling the natural grapefruit scent affects stress and appetite regulation, a factor associated with neurotic binge eating disorder, through EEG measurements and subjective assessments. Furthermore, the study anticipates the utilization of its findings as foundational data for the development of aromatic cosmetics that induce positive physiological and emotional responses associated with appetite regulation in the future.

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Theoretical Background

Electroencephalogram

Brainwaves are objective and non-invasive signals that indirectly measure continuous changes in brain activity by capturing the electrical activity of the neurons comprising the brain through scalp electrodes. Because the brain responds differently to external stimuli or information inputs, analyzing brainwave patterns enables the obtention of objectified and quantified results. Therefore, brainwaves serve as indicators of various mental physiological functions such as arousal, activity, stability, and anxiety, making them valuable for understanding the organ's functions [7].

In the process of generating EEG signals, synapses are formed between nerve cells in the cerebral cortex under the meninges, the inner membranes of the brain, and neurotransmitters are secreted from the presynaptic nerve terminal, and the secreted neurotransmitters bind to ion channels on the postsynaptic membrane, causing them to open (Fig. 1). When the ion channel opens, sodium (Na^+) ions flow into the cell through the Na^+ channel, and potassium (K^+) ions flow out of the same, causing a potential difference between the two ends of the cell membrane, resulting in a voltage that induces the flow of a current, which creates an electric field. This change in the electric field creates a magnetic field, and the change in the magnetic field creates an electric field; therefore, it is possible to measure EEG signals of 10~50uV by placing electrodes on a person's scalp [8].

The frequency bands of brain waves are categorized into delta waves (0–4 Hz), theta waves (4–8 Hz), alpha waves (8–13 Hz), beta waves (13–30 Hz), and gamma waves (30–50 Hz). Alpha waves are strong in the occipital lobe during relaxed states, such as when meditating and at rest, and the brainwaves of healthy, non-stressed people tend to be dominated by alpha waves [8-9].

When performing an EEG, the position of the electrodes on the head is determined by the international electrode placement method, with the 10–20-electrode system being the most commonly used. Depending on where the electrodes are placed, they are labeled as Fp (Frontpolar), F (Frontal), C (Central), P (Pariental), T (Temporal), O (Occipital), A (Auricular), and Z (Zero), and each measurement point is located in the following proportions: 10%, 20%, 20%, 20%, 20%, 20%, and 10%, with the actual distance between the nasal and occipital poles being 100 and the interelectrode distance being 5–6 cm [10].

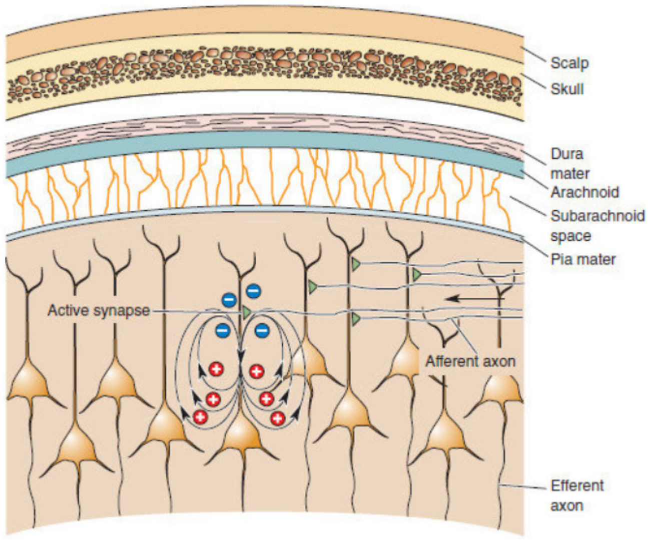


Figure 1: How Brainwave Signals Are Generated [8].

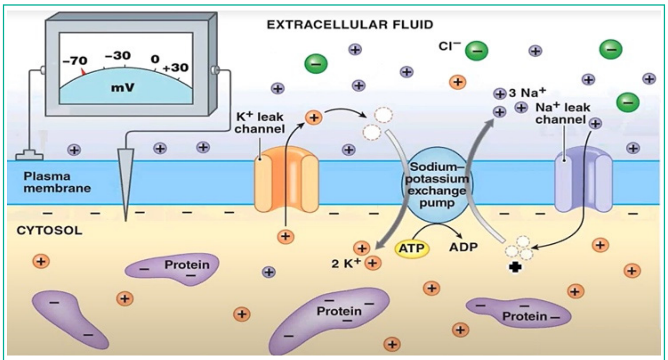


Figure 2: Electrical flow in and out of nerve cells and brain wave signals [8].

Stress

Stress has become a part of everyday life for modern people, and while moderate stress is beneficial for personal growth and development, excessive stress can hinder productivity, creativity, and physical and mental well-being, possibly leading to psychological instability when stress leads to fatigue [11]. Selye (1936), who began the study of stress by using the term "stress," defined and described the stress response as the General Adaptation Syndrome (GAS). GAS is the body's attempt to defend against stress, which was divided by Selye into three stages: warning, resistance, and exhaustion [12]. Stressors include physiological, psychological, environmental, social, and cultural factors. The stress response is associated with an imbalance in metabolism caused by the concentration of the stress hormone known as cortisol. When people are stressed, their emotions and thoughts are stimulated and the hypothalamus releases Corticotropin-Releasing Hormone (CRH), which stimulates the pituitary gland. The release of CRH triggers the production of corticosteroids by the adrenal cortex, which induces increments in blood pressure and pulse rate, causing anxiety [13-14]. In addition, the discrepancy between a person's actual and perceived body shapes due to distorted social body shape perceptions in women in their 20s can cause significant stress related to weight control in college women in their 20s, who are more concerned about their appearance than women of other age groups, leading to binge eating, purging, and other unnecessary weight control behaviors [15].

Bulima Nervosa

Young women are keen on controlling their weight to maintain a beautiful body shape, and many of them are dissatisfied with their body shape and are trying to lose weight unnecessarily. In a study of obesity and body image perception, 35.5% of women in their 20s and 30s reported that their perceived body size exceeded the actual one, and in a study of obesity, body image perception, and weight control, 55.6% of women with a BMI in the underweight range and 49.0% of those with a BMI in the normal range reported having tried to control their weight. Attempting to control weight using inappropriate methods such as fasting, purging, or medication can lead to bulimia nervosa due to the ineffectiveness of weight control or the anxiety and stress of not reaching their target weight [16].

Bulimia nervosa is defined as binge eating behavior, which involves eating significantly more food than most people can consume in a short period of time, followed by repeated compensatory behaviors such as vomiting and purging to prevent weight gain. These binge eating behaviors and inappropriate compensatory behaviors must occur on average at least twice a week for three months, and the person's body shape and weight must have an excessive influence on self-evaluation [17]. Bulimia nervosa is most prevalent in people in their 20s and 30s, with a higher prevalence in women than men [18], and female college students have been shown to have higher rates of binge eating and bulimia nervosa symptoms compared with women in the general workforce [19].

The Grapefruit

The grapefruit is a citrus fruit that is similar in flavor to grapes and is called a grapefruit because it runs like a grapevine. The name "grapefruit" is said to have originated from the Japanese translation of the Portuguese word "Zamboa," which means grapefruit [20]. Grapefruit essential oil, which is obtained by cold-pressing the peel of the grapefruit, is a clear liquid with a fresh, light, fruity odor that is a mixture of lemon and orange. The main component of grapefruit oil is d-limonene, which is more than 90%, and other components include geraniol and citronellal. Grapefruit oil has a balancing effect on the central nervous system, such as relieving stress and stabilizing bipolar disorder. Professor Katsuya Nagai and Professor Emeritus Akira Niijima of Niigata University in Japan conducted an experiment on mice for six weeks, in which it was found that the group that smelled grapefruit essential oil was about 20 grams lighter than the group that did not smell it and that the mice that smelled grapefruit essential oil ate about 70% less, showing that smelling grapefruit essential oil had a dietary effect. In addition to being low in calories and sugar, the grapefruit also contains a compound called naringin, which burns unnecessary fat and suppresses appetite, making it an effective weight loss aid [21].

Scent Inhalation

The sense of smell is the most primitive of the human senses, and when olfactory cells in the nose are stimulated, we perceive odors through electrical signals. Scent particles delivered through the olfactory cells can affect a person's memory and psychological state and even regulate hormonal balance, which raises the possibility that scents can be used to heal both physically and emotionally [22].

When inhaled, scent molecules suspended in the air enter the nose and travel deep into the nasal cavity where olfactory receptors are located, where they dissolve in mucus and remain for a period. While the scent molecules are in the mucus, they are detected by olfactory receptors. One specific olfactory receptor is recognized by different nerve cells with one type of olfactory receptor, which makes the odor detection system flexible, allowing it to detect thousands of molecule-receptor combinations. When an olfactory receptor binds to a molecule, the olfactory nerve cell is activated and sends a signal to the brain, and the information carried by the olfactory nerve cell reaches the olfactory reticulum, which is made up of neurons that read the information about the scent molecule, encode it, and relay it to the olfactory bulb (recognition), the olfactory cortex and hippocampus (memory), and the amygdala (emotion), respectively [23]. Olfactory stimulation by these scent molecules is transmitted to various parts of the brain, triggering in-situ neural activity, so brain activity can be analyzed using the EEG to scientifically understand the function of scent [24].

Scent inhalation is a non-invasive method that uses natural essential oils extracted from plants and absorbed into the body through the skin or sense of smell to produce a holistic healing effect. The scent molecules inhaled through the nose have a systemic effect on the entire body, which is effective in calming the mind and body and stimulating mood. It also reduces increased blood pressure, pulse rate, and salivary cortisol secretion, blood cortisol secretion, and blood cortisol levels. Scent inhalation plays a critical role in the physiological effects of stress and mood and changes in these brain functions.

Research Methods

Study Population

The participants of this study were 32 females aged 20–25 years who were undergraduate students at Ga University in Seongnam, Gyeonggi-do, Korea. The subjects did not have grapefruit allergy, had no olfactory or neuropsychiatric disorders during the experimental period, and were neither pregnant nor receiving medication during the study period. All participants gave their informed consent to participate in the study.

Research Materials

The essential oils used in the study were grapefruit oil and bergamot mixed in a 3:2 ratio and formulated in a perfume with 15% fragrance, based on previous research that shows synergistic effects of these two when blended rather than used individually [26].

Research Design

The experiments were conducted in a noise-free environment, and after each participant was finished, the room was ventilated for 15 minutes to ensure that no scent remained before the next subject was tested. The olfactory function (perceptual and threshold) of the subjects was checked before the experimental treatment, all metal accessories and electronics were removed to eliminate noise, and the subjects were asked to relax in a comfortable position for 3 minutes before the EEG measurement. After the EEG device was fitted, the EEG was performed while smelling a stimulating scent (cis-3-Hexenol) for 60 seconds with the eyes closed, followed by 60 seconds of the grapefruit scent. The EEG was then performed while smelling a stimulating scent (cis-3-Hexenol) for 60 seconds, followed by a control pomegranate scent for 60 seconds, for a total of 4 minutes. The scent was perceived by holding a container of scented cigar paper 5 cm away from the nose, as advised by an expert. After the EEG measurement was completed, participants were asked to move to another room to complete a subjective evaluation using a questionnaire. Before and after inhaling the grapefruit scent using the sachet, participants were asked to complete a stress questionnaire and an appetite questionnaire every 15 minutes for 1 hour.

Measurement Tools

Olfactory function tests: The scent survey for the screening test was used to assess the olfactory function of the subjects in this study (Yang et al. 2018). It is a questionnaire that scores the familiarity of 20 odor substances, including coffee, lemon, cucumber, apple, and fish, and scores each odor substance according to the degree of familiarity using a five-point Likert scale: 5 for very familiar, 4 for familiar, 3 for moderately familiar, 2 for not familiar, and 1 for not familiar at all, with a total of 100 points for each item. A score of ≤74 is indicative of olfactory decline [27].

EEG Equipment: For EEG measurements, we used the Starstim 8 product from Neuroelectrics. Electrodes were attached to AF3, AF4, F3, F4, C3, C4, O1, and O2 using the international electrode placement method, the 10–20 electrode system, based on expert advice and previous studies on the EEG following scent stimulation by Kang et al. (2015), Kwon et al. (2013), Lee et al. (2021), and Kang et al. (2020) [28-31].

Stress tests: The stress questionnaire used in this study was the Stress Response Inventory (SRI) published by Koh et al. in 2000. The SRI was developed to measure stress response, which includes four stress responses (behavioral, cognitive, social, and emotional) and consists of four domains and 39 items. Each domain consists of 9 behavioral responses, 11 cognitive responses, 11 physical responses, and 8 emotional responses. The seven subscales are categorized into tension, frustration, fatigue, depression, anger, and aggression, and are scored on a five-point Likert scale (0-4) [32].

Appetite assessment: Appetite was assessed in this study using a visual analog scale that assesses appetite at 15-minute intervals for a total of 60 minutes and is divided into 10 bins, with 0 being the absence of appetite and 10 being the highest possible appetite [33].

Analysing Data

To analyze the changes in EEG following grapefruit scent inhalation, a 0.1-50 Hz bandpass filter was applied to reduce noise, and a low-loss Multitap Spectrum Estimation in the frequency domain was used to calculate the Power Spectrum Density (PSD) in the range of delta, theta, alpha, beta, and gamma waves. Topographical maps were used for comparative analyses to determine the differences between the pungent and grapefruit scents and the pungent and pomegranate scents. Statistical analyses were performed using SPSS. The Mann–Whitney U test was used to test for differences between the irritating and grapefruit scents as measured by EEG. The demographics and olfactory function of the participants were analyzed using descriptive statistics, and the effect of stress before and after grapefruit scent inhalation was analyzed using the Mann–Whitney U test. Differences in the timing of the six phases of appetite according to BMI body mass were analyzed using the Friedman test, and Pearson correlation analysis was performed to correlate subjective ratings of stress and appetite with EEG data. The threshold for statistical significance was set at $p < 0.05$.

Results

Six of the 32 women aged 20–25 were excluded from the analysis due to errors in data collection.

Study Participant Characteristics

Participant BMI analysis: BMI distribution was determined using descriptive statistics for the 26 study subjects. According to the World Health Organization's BMI standards, 18 (69.2%) had a normal weight, 6 (23.1%) were overweight, and 2 (7.7%) were underweight.

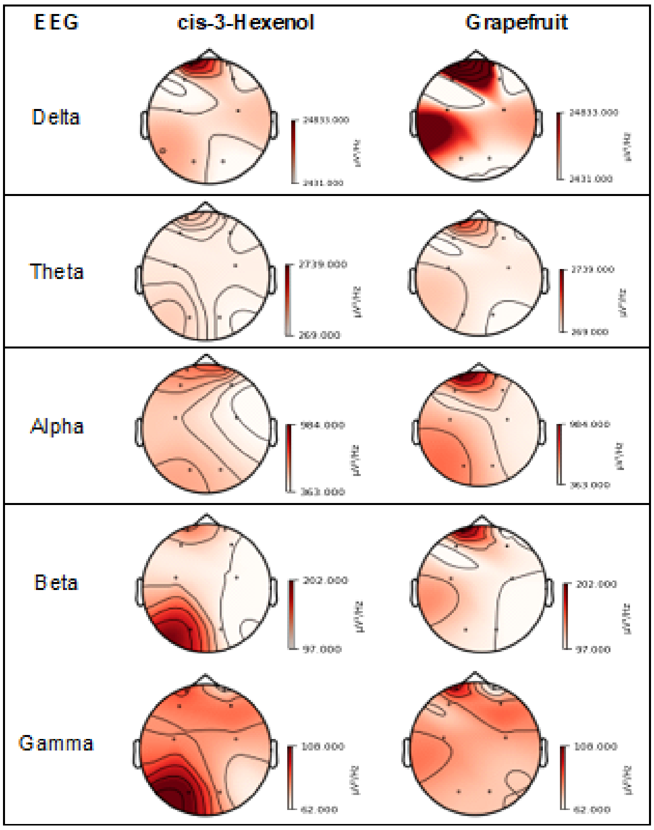
Frequency analysis of the olfactory function of our study participants: The olfactory function (perceptual and threshold) scores range from 75 to 100. The mean score of our study participants was 82.12. All subjects scored above 75 on the olfactory function test, confirming that they all partciapanthad a normal olfactory function.

EEG Aata Analysis Results

EEG Topographical map changes according to scent inhalation: EEG topographical map changes with scent inhalation The difference between inhaling an irritating scent and inhaling the grapefruit scent was compared using the topographical map. The topographical map shows the amount of PSD, measured in V^2/Hz. The PSD is a linear artifact of simple oscillations, assuming that the EEG is oscillating at a specific frequency, and the magnitude or power of each frequency component is decomposed and displayed [8].

Comparing the topographical maps of inhalation of the stimulating scent and grapefruit scent, it was found that the amount of PSD in the Delta, Theta, and Alpha regions was higher when inhaling the grapefruit scent than when inhaling the stimulating scent across all regions; conversely, the amount of PSD in the O1 region was higher when inhaling the stimulating scent in the Beta and Gamma regions (Table 1).

Table 1: Topographical map of grapefruit scent inhalation.



Based on the above results, it can be concluded that the stimulating scent used in the experiment induced brain activation in the occipital and anterior regions, and that grapefruit scent inhalation had a stable effect on the EEG activated by the stimulating scent.

The Mann–Whitney U test was used to analyze the calming effect of scent inhalation on the brain, showing an increase in alpha waves at EEG point AF3 from a mean of 0.13783±0.28062 for inhaling the irritating scent to a mean of 0.33093±0.57377 for inhaling the grapefruit scent, and at AF4 from a mean of 0.44459±2.3405 for inhaling the irritating scent. In F3, alpha wave increased from a mean of 0.27929±0.59898 to a mean of 0.60799±1.19305 when inhaling the irritating aroma, and in C4, alpha wave increased from a mean of 0.43062±0.61242 when inhaling the irritating aroma (Table 2).

Thus, grapefruit scent inhalation resulted in a statistically significant increase in alpha waves activated during stress at four EEG sites (AF3, AF4, F3, and C4), suggesting that grapefruit scent inhalation has a stress-reducing and calming effect on the brain.

Results of Subjective Evaluation of Stress and Appetite

Analysis results of stress changes before and after inhaling grapefruit scent: Per the results of our analyses, 31 out of 39 questions were statistically significant at the 95% confidence level, with a decrease in stress after inhalation compared with before inhalation (Table 3), suggesting that grapefruit scent inhalation is effective in reducing stress.

Table 2: Comparison of alpha differences between cis-3-Hexenol and Grapefruit.

Position	cis-3-Hexenol	Grapefruit	*p*-value***
AF3	0.13783 ± 0.28062	0.33093 ± 0.57377	.001
AF4	0.44459 ± 0.71459	1.36463 ± 2.34051	.001
F3	0.27929 ± 0.59898	0.60799 ± 1.19305	.021
F4	0.21360 ± 0.49725	0.81446 ± 1.85936	.192
C3	0.12501 ± 0.20664	0.61552 ± 1.10523	.127
C4	0.12061 ± 0.17167	0.43062 ± 0.61242	.010
O1	0.32396 ± 0.44101	1.23174 ± 2.69500	.186
O2	0.38578 ± 1.08710	0.82335 ± 2.09914	.055

Table 3: Mann–Whitney U test results before and after grapefruit scent inhalation.

Position	cis-3-Hexenol	Grapefruit	*p*-value***
AF3	0.13783 ± 0.28062	0.33093 ± 0.57377	.001
AF4	0.44459 ± 0.71459	1.36463 ± 2.34051	.001
F3	0.27929 ± 0.59898	0.60799 ± 1.19305	.021
F4	0.21360 ± 0.49725	0.81446 ± 1.85936	.192
C3	0.12501 ± 0.20664	0.61552 ± 1.10523	.127
C4	0.12061 ± 0.17167	0.43062 ± 0.61242	.010
O1	0.32396 ± 0.44101	1.23174 ± 2.69500	.186
O2	0.38578 ± 1.08710	0.82335 ± 2.09914	.055

Analysis results of appetite changes before and after inhaling

grapefruit scent: The Friedman test was used to analyze changes in appetite at six stages before and after grapefruit scent inhalation using an appetite questionnaire. The results showed that there was a statistically significant difference in the gradual decrease in appetite with grapefruit scent inhalation between subjects with normal BMI and overweight subjects. In addition, when analyzing all subjects, there was a statistically significant decrease in appetite (Tables 4 & 5). Therefore, it can be concluded that grapefruit scent inhalation reduces appetite and that grapefruit scent inhalation can help control appetite.

Correlation Analysis Results Between Subjective Evaluation and PSD

Correlation analysis results between difference and PSD before and after subjective stress assessment: The Pearson correlation analysis was performed to correlate the pre and post differences in subjective stress assessments with the theta wave at AF3 when inhaling the stimulating fragrance, and the correlation analysis of the theta wave at AF3 showed a negative correlation with r = −0.33836, although it was not statistically significant (p = 0.90). The correlation analysis of the delta wave PSD with the pre and post differences in the total subjective evaluation of stress showed a significant negative correlation (r = −0.396329, p = 0.045); so, it can be concluded that the inhalation of stimulating incense induced stress in the subjects. Among the questionnaire items, the greater the difference between the pre and post decrease in the fatigue item, the greater the positive

Table 4: Six appetite levels by BMI category.

Position	cis-3-Hexenol	Grapefruit	*p*-value***
AF3	0.13783 ± 0.28062	0.33093 ± 0.57377	.001
AF4	0.44459 ± 0.71459	1.36463 ± 2.34051	.001
F3	0.27929 ± 0.59898	0.60799 ± 1.19305	.021
F4	0.21360 ± 0.49725	0.81446 ± 1.85936	.192
C3	0.12501 ± 0.20664	0.61552 ± 1.10523	.127
C4	0.12061 ± 0.17167	0.43062 ± 0.61242	.010
O1	0.32396 ± 0.44101	1.23174 ± 2.69500	.186
O2	0.38578 ± 1.08710	0.82335 ± 2.09914	.055

Table 5: Results of Friedman test analysis of 6-level change in appetite by BMI category.

Position	cis-3-Hexenol	Grapefruit	*p*-value***
AF3	0.13783 ± 0.28062	0.33093 ± 0.57377	.001
AF4	0.44459 ± 0.71459	1.36463 ± 2.34051	.001
F3	0.27929 ± 0.59898	0.60799 ± 1.19305	.021
F4	0.21360 ± 0.49725	0.81446 ± 1.85936	.192
C3	0.12501 ± 0.20664	0.61552 ± 1.10523	.127
C4	0.12061 ± 0.17167	0.43062 ± 0.61242	.010
O1	0.32396 ± 0.44101	1.23174 ± 2.69500	.186
O2	0.38578 ± 1.08710	0.82335 ± 2.09914	.055

correlation with the delta wave PSD in O1 when grapefruit scent was inhaled, with a statistically significant difference of r = 0.41472 (p = 0.05). Also, there was a significant positive correlation between the score of the somatization item and the delta wave PSD in 01 when the grapefruit scent was inhaled (r = 0.41970, p = 0.032). There was also a significant positive correlation between the difference in the frustration item score reduction and the difference in the depression item score reduction, and the delta wave PSD in 01 (r = 38822, p = 0.05); however, this correlation was not statistically significant. Also, the decrease in the depression item's score was positively correlated with the delta wave PSD in O1 (r = 0.37685, p = 0.05); however, this correlation was not statistically significant. Therefore, it can be said that grapefruit scent inhalation effectively reduced stress in our study participants.

Results of correlation analysis between difference before and after subjective appetite evaluation and PSD: The Pearson correlation analysis was performed to determine the correlation between the pre and post difference in subjective appetite ratings and EEG PSD, and the difference in decreased appetite was positively correlated with the theta wave PSD at F3 (r = 0.33726, p = 0.092); however, this correlation was not statistically significant. It was also positively correlated with the alpha wave PSD at F3 at (r = 0.33451, p = 0.094) but the correlation was not statistically significant. In addition, the difference in decreased appetite was positively correlated with the PSD of alpha waves in C3 (r = 0.34618, p = 0.087); however, the correlation was not statistically significant. Therefore, although they were not statistically significant, there were positive correlations between the difference in decreased appetite and the PSD of theta waves in F3 and alpha waves in C3. There were also positive correlations with the PSD of theta waves in F3, and the PSD of alpha waves in C3, and these correlations were directly proportional to the positive effect of grapefruit scent inhalation on appetite control.

Consideration and Conclusion

Along with the problem of obesity among female college students in their 20s, bulimic binge eating behaviors due to stress and substance misuse due to improper dieting have emerged as important issues, and it has been found that EEG measurement is a way of measuring and managing stress [34], and studies have been conducted on EEG changes such as stress [35], concentration [36], sleep [37], and brain activity [38] in response to scent inhalation. Therefore, in this study, we analyzed the changes in brain waves following grapefruit scent inhalation using the EEG to determine whether inhaling the natural grapefruit scent is effective in controlling stress and appetite, which are determinants of bulimia nervosa, and analyzed subjective ratings of both factors before and after grapefruit scent inhalation to determine its effect on appetite. The results of the study were as follows

First, the topographical map of grapefruit scent inhalation showed high PSD in the delta, theta, and alpha regions and increased alpha waves at EEG points AF3, AF4, F3, and C4, confirming the calming and stress-reducing effects of grapefruit scent inhalation.

Second, the results of the subjective assessment of stress showed a statistically significant decrease in stress after inhalation compared with before inhalation in most items, confirming the stress-reducing effect of grapefruit scent inhalation.

Third, the subjective evaluation of appetite showed a statistically significant decrease in appetite in normal-weight and overweight subjects, and a statistically significant decrease in appetite in all subjects, confirming the appetite-reducing effect of grapefruit scent inhalation.

Fourth, the correlation analysis between the subjective assessment of stress and EEG PSD showed a positive correlation between some items of the stress questionnaire and delta wave PSD with a statistically significant difference, confirming the stress-reducing effect of grapefruit scent inhalation.

Therefore, this study was conducted to verify the stress-reducing and appetite-control effects of inhaling the natural grapefruit scent using the EEG, stress questionnaire, and appetite evaluation sheet, which are objective experimental indicators. Therefore, this study is significant in that it attempted to consider both physiological and emotional aspects of the human body, and it is believed that it will be used as a basis for the development of emotional science cosmetics that can induce positive physiological and emotional responses related to appetite control in the future. In addition, based on the results of this study, we would like to recommend a study that considers the standard error in a repeated-measures experiment of objective and subjective evaluation of fragrances, and recommend a study that secures various age groups and sample numbers beyond the specific age group of the 20s.

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