International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Spearmint Aroma and Brainwave Dynamics: A QEEG Analysis of Theta-to-Alpha Ratio

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Abstract:
Theta and alpha brainwaves are prominent frequencies in the human brain associated with distinct states of consciousness and cognitive processes. Theta waves, oscillating at 4-8 Hz, are commonly observed during deep relaxation, meditation, and creative states. On the other hand, alpha waves, ranging from 8-12 Hz, are prevalent during wakeful relaxation and a state of alertness. The balance between theta and alpha rhythms reflects an individual's cognitive and emotional state, making it a valuable metric for investigating the effects of external stimuli such as aroma. To explore the effect of spearmint aroma inhalation on brainwave dynamics, a controlled study was conducted involving thirty female participants exposed to the scent of spearmint essential oil. Quantitative electroencephalography (QEEG) recordings were obtained from 19 scalp electrodes distributed in six brain regions before and after the exposure period to assess changes in theta-to-alpha ratios. Participants' subjective experiences were also documented to correlate with the neurophysiological findings. QEEG analysis revealed a significant increase in theta-to-alpha ratios following exposure to spearmint aroma compared to baseline measures in all the brain regions: Prefrontal ($p=0.000$), frontal ($p=0.000$), central ($p=0.000$), parietal ($p=0.000$), temporal ($p=0.000$) and occipital ($p=0.000$). This study provides empirical evidence supporting the beneficial effects of spearmint aroma on brainwave dynamics, as evidenced by the modulation of theta-to-alpha ratios.

Keywords: Aroma, spearmint, Brain wave, QEEG.

1. Introduction:

The human brain, an intricate and mysterious organ which contains the answers to our thoughts and the mysteries has been a continuous endeavor for scientists and investigators [1]. Along this journey, a potent instrument has arisen: Quantitative electroencephalography (QEEG). Through the application of sophisticated signal processing methods and algorithms, QEEG dissects the captured brainwave patterns into distinct frequency ranges, each linked to particular mental conditions and cognitive functions [2].
Brain waves are classified into different frequency bands, typically ranging from very slow to very fast. The main frequency bands include: Delta (0.5 - 4 Hz): Predominant during deep sleep or in cases of brain injury; Theta (4 - 8 Hz): Associated with deep relaxation, daydreaming, and light sleep, these waves tend

to dominate during states of meditation; Alpha (8 - 12 Hz): Present when the brain is relaxed but alert, often seen during meditation or when closing one's eyes and Beta (12 - 30 Hz): Associated with active thinking, problem-solving, and concentration [1].

The interplay between aroma and brain function has long fascinated researchers, with aromatherapy emerging as a promising avenue for understanding this complex relationship. Among the multitude of aromatic compounds, Mint has long been cherished for its refreshing aroma and culinary uses [3]. From peppermint to spearmint, this herbaceous plant has a plethora of beneficial properties. While its soothing qualities are well-known, studies have unearthed an intriguing correlation between spearmint inhalation and changes in brain waves [4]. This finding has piqued the interest of researchers and individuals seeking enhanced cognitive function. In this article, the relationship between spearmint aroma inhalation and theta-to-alpha ratio has explored, shedding light on its potential implications for mental well-being.

The theta to alpha ratio (Θ/α) is an index computed by taking the theta amplitude (μv^2) of the EEG as the numerator and alpha amplitude (μv^2) as the denominator. This ratio is utilized in alpha-theta neurofeedback training [5]. In the Alpha–Theta protocol, during alpha-theta feedback training, the theta to alpha ratio increases. This training, effective for conditions like post-traumatic stress disorder [6] and alcoholism [7], aims to induce a deep relaxation state similar to meditation or hypnagogic states. Participants are taught to increase theta waves relative to alpha waves, leading to a consciously induced state resembling unconscious relaxation [5]. A higher theta to alpha ratio in EEG readings indicates a dominance of theta wave activity over alpha wave activity, reflecting deep relaxation, enhanced creativity, and a state closer to sleep or deep meditation [8,9]. This ratio has various implications for mental well-being, promoting reduced stress, improved emotional balance, and creative thinking. Techniques such as mindfulness, deep relaxation practices, and creative activities can help achieve and maintain this state, contributing to overall psychological health and resilience [10,11].

To date, there have been recent EEG studies on various aromatic oil inhalation to improve participants mood, cognition and vigilance [4,12,13,14]. However, the scientific evidence of spearmint aroma's impact on brain waves remained limited. So, in this study, the effects of spearmint aroma on brainwave dynamics were explored, focusing on the modulation of theta-to-alpha ratios as measured by QEEG.

2. Materials and methods

This self-controlled trail was conducted in the physiology department of Bangabandhu Sheikh Mujib Medical University (BSMMU) with an aim to explore the effect of spearmint aroma inhalation on brain wave dynamics.

2.1 Selection criteria

Following an advertisement in the university campus and interview, total 35 volunteers were enrolled into the study. Selection for final recruitment were based on the following criteria: 1) 25-38 years of age; 2) female; 3) right-handed; 4) non-smoker and non-alcoholic; 5) no history of neurological disease or disorder of olfaction; 6) not taking any hormonal pill or drugs affecting CNS; 7) non-pregnant; 8) non lactating; 9) no history of trauma in recent times; 10) not allergic to herbal product [12]. Edinburg Handedness Inventory (EHI) scale was used for determining handedness [13] and also their normal sense of smell was assessed by n-butyl alcohol test [14].

2.2 Procedure

Ethical clearance for this study was approved by Institutional Review Board of the BSMMU. Informed consent of the participants was taken in written form explaining all aspect of the study and they were

instructed about the precautions to be taken on the day before experiment. Personal health status of the participants was also recorded which includes age, height, weight, BMI, blood pressure and smell test score. The subjects were advised to remove any metal ornaments or electronic device they were wearing. And oil free clean scalp was ensured too. To control for potential differences in nervous system response based on scent pleasantness, participants were asked to rate the pleasantness of the aroma on a 5-point Likert scale before the experiment. Only those who rated the aroma between 2 and 4 points were permitted to continue with the study [12].

EEG (traveler) BrainTech 32+ CMEEG 01(India) device was used for recording. According to international 10-20 system of electrode placement, total 19 scalp electrodes: FP1, FP2, Fz, F3, F4, F7, F8, Cz, C3, C4, P3, Pz, P4, T3, T4, T5, T6, O1, O2 were placed over the scalp and A1, A2 over the left and right ear lobe as reference electrode. These 19 electrodes were categorized into six brain regions: prefrontal (FP1, FP2), frontal (F7, F3, FZ, F4, F8), central (C3, CZ, C4), parietal (P3, PZ, P4), temporal (T3, T4, T5, T6), and occipital (O1, O2) [15]. Being seated in an armchair comfortably an EEG recording was obtained for 2 minutes at eye closed state as baseline recording. Noise free, dark room with temperature in between 23-25^{o} c were maintained while taking the recording.

2.3 Experimental design

Since this study was based on a single group acting as their own control, each of the participants went through a control session and an aroma session with an interval in between. Where in control session, they were exposed to water mist inhalation for 15 minutes followed by 2 minutes EEG recording afterwards; in aroma session they inhaled the aroma of spearmint essential oil in the form of mist and subsequent post inhalation EEG recording was taken in the same way. In both the sessions diffusers were used for mist generation that breaks the liquid by ultrasonic vibration without changing its chemical properties. The water used was filtered tap water and for the aroma session the essential oil was diluted with the same water at a ratio 1: 1000 [16].

2.4 Data processing

BrainTech 40+ Standard version 4.47a. software then processed the recording by using FFT (Fast Fourier Transformation) technique to extract the quantitative EEG data from the waves recorded. From each recording, 15 epochs of 4 sec. duration were averaged to attain data of 60 seconds for analysis. Then by dividing the power of theta wave by alpha wave power, Θ/α is calculated.

2.5 Statistical analysis

Median (IQR) was used for data expression and wilcoxon matched paired signed rank test was carried out to compare the Θ/α changes before and after the treatments and also to compare the post treatments conditions which re-ensured the findings. P value ≤ 0.05 was considered as statically significant.

3. Results

3.1 Demographic characteristics of the participants

During the study procedure there was attrition of 5 data. So finally, the research comprised 30 healthy women, aged between 25 and 38, with an average age of 32.4 ± 2.50 years. Their body mass index (BMI) fell within the range of 20.5 to 24.92 kg/m2, with an average BMI of 23.35 ± 1.11 kg/m2. Table 1 presents an overview of both demographic data and the outcomes of the smell test.

3.2 EEG analysis

QEEG analysis of Θ/α ratio revealed significant elevation of the ratio after the aroma intervention compared to baseline in all the brain regions: prefrontal (p= .000), frontal (p= .000), central (p= .000),

parietal (p= .000), temporal (p= .000) and occipital (p= .000) [Figure 1,2,3]. In addition, in these same regions, comparison between after water mist inhalation and after aroma inhalation also showed higher Θ/α ratio which reinforced the findings.

Table 1: General health status of the participants (N=30)

Parameters	Minimum	Maximum	Mean ± SD
Age (years)	28	38	32.4 ± 2.50
Body Mass Index (kg/m^2)	20.50	24.92	23.35 ± 1.11
Smell test score (Bottle no.)	9	11	10.3 ± 0.70

Data were expressed as mean ± SD. N- Total number of subjects

Figure 1: Theta-to-alpha ratio changes in prefrontal and frontal regions after inhalation of spearmint aroma and water mist session and their comparison to baseline condition. * Depicts comparison between post aroma EEG recording with that of the baseline. ***p < 0.001

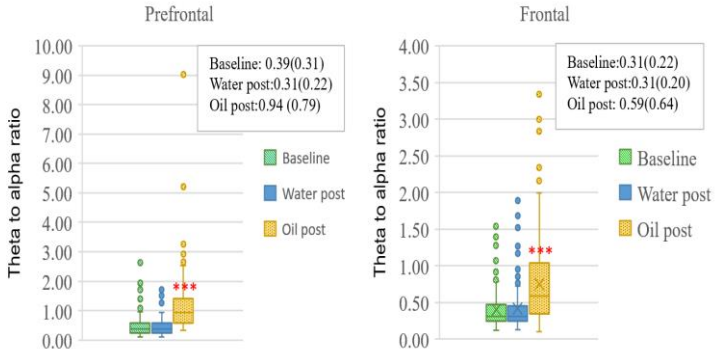


Figure 2: Theta-to-alpha ratio changes in central and parietal regions after inhalation of spearmint aroma and water mist and their comparison to baseline condition. * Depicts comparison between post aroma EEG recording with that of the baseline. ***p < 0.001

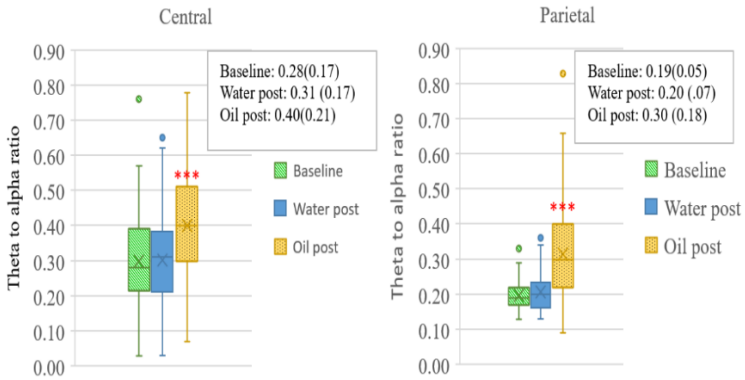
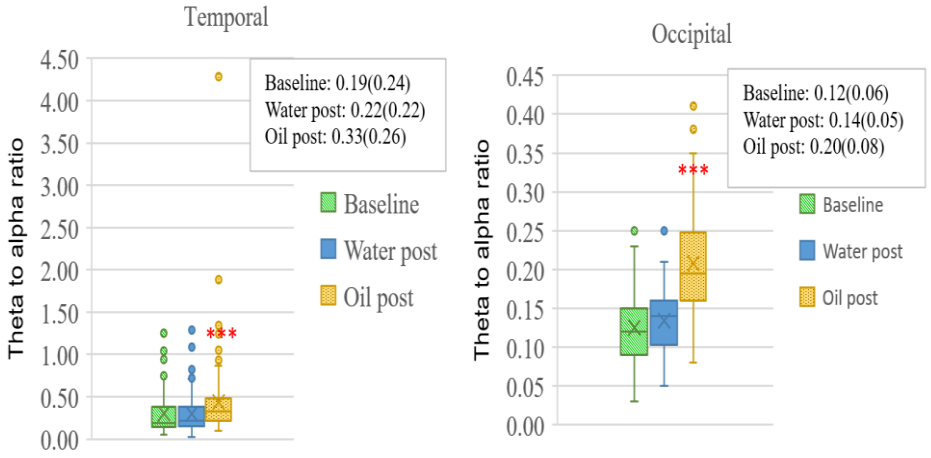


Figure 3: Theta-to-alpha ratio changes in temporal and occipital regions after inhalation of spearmint aroma and water mist session and their comparison to baseline condition. * Depicts comparison between post aroma EEG recording with that of the baseline. ***p < 0.001



4. Discussion:

Numerous recent studies have highlighted the capacity of aromatic oils to induce positive changes in human psychology and emotions by influencing the central nervous system (CNS) [4,12,13,14, 17]. Electroencephalography (EEG) has been used for quantitative analysis to evaluate the neurophysiological function of the human brain. In this research, we investigated the neurological impact of spearmint aroma to understand its effects on the human brain waves and cognitive function. The study compared changes in the absolute powers of theta divided by the absolute powers of alpha (Θ/α) brain waves before and after inhalation of spearmint aroma in each brain regions. To validate the results, these powers were also compared with those observed after a control session.

The observed modulation of theta-to-alpha ratios aligns with previous research on the relaxing properties of spearmint aroma [4]. In other studies, an elevation of Θ/α was also observed after a practicing meditation [5] which also indicated deeper physical and mental relaxation.

So, the activation of theta waves coupled with a relative suppression of alpha frequencies indicates a state conducive to a shift towards a more relaxed and introspective state induced by the scent and stress reduction. Interestingly, subjective reports from participants echoed these findings, with many describing feelings of calmness during the aroma exposure.

Possibly, the fragrant particles exert these effects after the aroma inhalation by interacting with olfactory receptors and transmitting signals to various regions of the brain, including the primary olfactory cortex, anterior olfactory nucleus, olfactory tubercle, piriform cortex, amygdala, and rostral entorhinal cortex. Once processed in the piriform cortex, this sensory information is relayed to higher brain centers, where it regulates cognition, memory, emotion, and behavior [18]. In addition to stimulating the olfactory pathway, these chemical particles are absorbed through both the nasal and lung mucosa into the systemic circulation. They then traverse the blood-brain barrier to reach the central nervous system (CNS), where they exert their influence on brain function [19]. While the precise underlying mechanisms are yet to be fully understood, it is conceivable that the aromatic compounds such as carvone, limonene, and 1,8-cineole present in spearmint oil interact with olfactory receptors, initiating cascades of neural activity that extend to various brain regions. It is likely that they act by enhancing the action of the inhibitory neurotransmitter

GABA, either by increasing its concentration or by synergizing with GABA receptors in the brain, thereby inducing a deeply relaxed and peaceful state [19,20].

5. Conclusion:

This study offers empirical evidence supporting the positive effects of spearmint aroma on brainwave dynamics, as demonstrated by the modulation of theta-to-alpha ratio and pave the way for innovative therapeutic interventions harnessing the power of aromatherapy for holistic well-being.

Limitations

The study didn't compare results across different age groups and sexes. It's crucial to account for potential confounding factors in QEEG measurements, like individual baseline brain activity, sex differences in smell, environmental influences, and methodological issues.

Recommendation

Further research exploring the long-term effects of spearmint aroma on brain function and its potential as an adjunctive therapy in clinical settings is warranted.

Acknowledgements

We extend our gratitude to all the participants for their generous time and effort. We also thank the research team members for their contributions to data collection and analysis.

Conflict of interest: None

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