Effects of Cranial Electrical Stimulation on Brain- A Brief Review

Khyatee Sharma1* and Aparna Sarkar2

1Amity Institute of Physiotherapy, Amity University, India
2Amity Institute of Physiology, Amity University, India

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*Corresponding author: Khyatee Sharma, Amity Institute of Physiotherapy, Amity University, Uttar Pradesh, India, Tel: 0120-4735694; Email: asarkar@amity.edu

Abstract
Cranial Electrotherapy Stimulation (CES) is a non-invasive therapeutic device that applies pulsed, alternating micro current (<1000 μA) transcutaneous to the head via electrodes placed on the earlobes, mastoid processes, zygomatic arches, or the maxilla-occipital junction. A functional magnetic resonance imaging study showed that CES causes cortical deactivation, producing changes similar to those produced by anxiolytics medication. Electroencephalographic studies show that CES increases alpha activity (increased relaxation), decreases delta activity (reduced fatigue), and decreased beta activity (decreased ruminative thoughts). Some Neurotransmitter studies revealed that CES increased blood plasma levels of beta endorphin, adrenocorticotropic hormone, serotonin, melatonin, norepinephrine and cholinesterase. CES also reduces cortisol level.

Keywords: Cranial electrical stimulation; Neurotransmitters; Cranial nerves; Electroencephalography

Introduction
Cranial Electrotherapy Stimulation (CES) is a US Food and Drug Administration-approved, prescriptive, noninvasive electro medical treatment that has been shown to decrease anxiety, insomnia, and depression significantly [1]. Micrcurrent electrical therapy and cranial electrotherapy stimulation are electro medical modalities that use low level currents that usually do not exceed one milliampere. Beneficial effects have been reported for a wide variety of pain, psychological distress, and addiction-related disorders. Pain is a complex process encompassing the entire nervous system. To achieve optimal results through electro medical intervention, the peripheral and central nervous systems should both be treated. CES induces a relaxed, alert state. It is a primary modality effective for controlling anxiety, depression, insomnia and generalized stress ubiquitous in pain patients. In addition, there is mounting evidence that CES can enhance cognitive functions [2-4].

CES is a well-documented neuroelectrical modality that has been proven effective in some good studies of fibromyalgia (FM) patients. CES is no panacea but, for some FM patients, the modality can be valuable. Controlled studies provide evidence that CES is effective for anxiety, headaches, fibromyalgia, smoking cessation, drug withdrawal symptoms, and (in some but not all studies) pain [5-10]. The majority of controlled studies have evaluated the efficacy of CES for treatment of anxiety, although most were performed in nonclinical samples [6,8]. CES applied to the earlobes was found to reduce symptoms of Generalised Anxiety Disorder (GAD) [11]. Despite empirical evidence for treatment efficacy for these syndromes, skepticism remains as to how application of micro current to the earlobes or scalp could effect these clinical changes, likely because of the dearth of studies of its mechanism. As brain stimulation techniques increasingly hold promise for treatment of neurological and psychiatric disorders, better understanding of their mechanisms of action is crucial to further improve their efficacy, develop new technologies, and evaluate their safety.

It remains unclear how the electrical current from CES may alter brain activity. Forty-two to 46% of the applied CES current enters the brain, with the highest levels of current recorded in the thalamus [16-17]. One theory suggests that the cranial Alternating Current (AC) stimulation interferes with ongoing brain wave oscillations by introducing cortical noise [18]. Perhaps the most investigated effects to date of CES have come from Electroencephalographic (EEG) studies, which have found recordings to be altered during and after treatment with CES. Applying CES at 0.5- and 100-Hz with simultaneous EEG resulted in a downward shift in mean alpha frequency, with greater effect for 100-Hz stimulation [12]. CES also results in a decrease in alpha band median frequency and beta band power fraction [13]. These changes are similar to EEG changes in traine-d meditators, and may be associated with a relaxed state [14]. A
Recent functional magnetic resonance imaging study showed that CES causes cortical brain deactivation in midline frontal and parietal regions of the brain after one 20-minute session treatment [4]. Although it remains unclear if these alterations in brain wave oscillation patterns are a cause or effect of improved clinical states, pulsed current may interrupt nervous system function [15].

**Neuro physiologic effects and research studies**

CES is believed to affect the subcortical brain structures known to regulate emotions, such as reticular activating system, thalamus, and hypothalamus, neurotransmitter function hormone production via the hypothalamus-pituitary axis [2]. CES treatments induce significant changes in the electroencephalogram, increasing alpha (8-12 Hz) relative power and decreasing relative power in delta (0-3.5 Hz) and beta (12.5-30 Hz) frequencies [3]. Increased alpha correlates increased relaxation and increased mental alertness or clarity. Decreased delta waves indicate a reduction in fatigue. Beta waves reductions between 20 and 30 Hz correlate decreases in anxiety, ruminative thoughts and obsessive/compulsive like behaviours. In regards to how the current reaches the brain, because this study used earlobe electrodes, the alternating micro current may initially stimulate afferent branches of cranial nerves. Stimulation may initially occur at branches of the facial, glossopharyngeal, and/or the vagus nerves that originate near the electrode placement on the earlobe, then are carried to the brainstem, the thalamus, and finally the cortex.

Two different clinically effective frequencies (100 or 0.5 Hz) were associated with brain deactivation, but the amplitude of current was not. This provides additional mechanistic evidence that CES may exert its effects through interruption of normal cortical activity, possibly through the introduction of high- or low-frequency noise that interferes with certain brain oscillation patterns [19]. CES treatments have been found to induce changes in neuro hormones and neurotransmitters that have been implicated in psychiatric disorder; Substantial increases in beta endorphins, adrenocorticotrophic hormone, and serotonin; moderate increases in melatonin and norepinephrine, modest and unquantified increases in cholinesterase, gamma aminobutyric acid and moderate reduction in cortisol [20-21].

**Aims and objective**

To find out the effect of cranial electrical stimulation on brain waves and plasma level of neurotransmitters (Figure 1).

![Figure 1](image-url)
**Discussion and Conclusion**

Cranial electrical stimulation treatments have been found to induce changes in neurotransmitters that have been implicated in psychiatric disorders. Authors suggested that there is a substantial increase by 98% in Beta endorphin which helps in decreasing pain. Adrenocorticotropic hormone is increased by 75% which promotes haemostasis; serotonin is increased by 50% it helps in improving mood, increases pain tolerance and decreases insomnia. There is 25% increase in Melatonin which induces sleep, Norepinephrine levels are elevated to 24% that improves pleasure and increases arousal. Cortisol is decreased by 18% helpful in reducing stress response. Increase in cholinesterase by 8% induces relaxation. Increase in Gamma-Aminobutyric acid decreases spasticity [22].

According to neuroscientists, analysing electroencephalograms of people submitted to tests in order to research the effect of decreasing the brain rhythm, the attentive relaxation or the deep relaxation, produce significant increases in the levels of beta-endorphin, norepinephrine and dopamine, linked to feelings of enlarged mental clarity and formation of remembrances, and that this effect lasts for hours and even days. It is an ideal state for synthetic thought and creativity, the proper functions of the right hemisphere. As it is easy for the hemisphere to create images, to visualise, to make associations, to deal with drawings, diagrams and emotions, as well as the use of good-humour and pleasure, learning is better absorbed if these elements are added to the study methods [23].

**Mechanism of action of cranial electrical stimulation**

Cranial electrical stimulation through ear dip method in which electrodes are placed over the ear lobes stimulate afferent branches of cranial nerves like Facial nerve, Glossopharyngeal nerve and vagus nerve, it is believed to affect the subcortical brain structures known to regulate emotions, such as reticular activating system, thalamus, and hypothalamus, neurotransmitter function hormone production via the hypothalamus-pituitary axis. Cranial electrical stimulation produces cortical noise in ongoing brain wave oscillations producing rhythmic oscillations in the cortex of the brain as it is alternating current stimulation.

**References**

22. Daniel L Krsch, Francine Nichols (2013) Cranial electrical stimulation treatments have been found to induce changes in neurotransmitters that have been implicated in psychiatric disorders. Authors suggested that there is a substantial increase by 98% in Beta endorphin which helps in decreasing pain. Adrenocorticotropic hormone is increased by 75% which promotes haemostasis; serotonin is increased by 50% it helps in improving mood, increases pain tolerance and decreases insomnia. There is 25% increase in Melatonin which induces sleep, Norepinephrine levels are elevated to 24% that improves pleasure and increases arousal. Cortisol is decreased by 18% helpful in reducing stress response. Increase in cholinesterase by 8% induces relaxation. Increase in Gamma-Aminobutyric acid decreases spasticity [22].