HIGH SCHOOL EDITION
Journal of Student Research
Volume 13 Issue 4 (2024)

Correlation Of Different Acupunctures and Electroencephalogram Devices in Response to Alzheimer's Disease, Epilepsy, Chronic and Acute Pain, And Parkinson's Disease

Ryan Tiong[1] and Eric McCoy[#]

[1]Irvington High School, USA
[#]Advisor

ABSTRACT

Numerous studies have demonstrated the effectiveness of acupuncture in treating Alzheimer's disease (AD), epilepsy (EP), pain, and Parkinson's disease (PD). The acupoints used on different diseases should be different. This paper identifies the commonalities among these studies across different treatments. Additionally, electroencephalogram (EEG) has been reported to be useful in detecting AD, diagnosing EP, monitoring pain, and identifying PD. However, researchers need more consensus regarding the optimal signal-processing techniques for EEG in each disease. We will present what is the most prominent process for each condition. Furthermore, we explore the advantages of combining EEG with acupuncture. The results of this study will serve as a foundational direction for further in-depth research and implementation.

Introduction

Acupuncture has been a prolonged practice of Traditional Chinese medicine (TCM) evolving over thousands of years ("Acupuncture"). The practice includes puncturing thin needles into the skin in certain body parts, otherwise known as acupoints. This will stimulate the central nervous system releasing chemicals into the muscles, spinal cord, and brain. These needles can also be adjusted by hand or stimulated using small electrical currents, known as electroacupuncture (EA). Often, EA stimulation is applied to the acupuncture needle, with stimulation frequencies of 15-30 Hz proving more effective than lower frequencies of 2-3 Hz in triggering peptide release (Racke, 1989). Low and high frequencies are shown to be effective: however, higher frequencies during EA tend to have more promising results (Li 2016). Alongside these practices, laser acupuncture (LA) can also be used to benefit patients. LA is a technique that uses nonthermal, low-intensity laser irradiation to stimulate acupuncture points, offering a pain-free, safer alternative to traditional acupuncture with minimal adverse effects (Chon 2019). Laser acupuncture involves minimal sensation and short treatment duration, reducing bleeding risks, infections, and trauma (Chon 2019). Some key acupoints used in treatments are ST36 (Stomach Channel), GV20 (Governing Vessel), SP6 (Spleen Channel), LI4 (Large Intestine Channel), and KI3 (Kidney Channel) ("Acupuncture points…"). Figure 1 shows a list of acupoints in their locations ("Understanding the Body Meridians").

Many diseases can be studied with an electroencephalogram (EEG). EEG is a technique used to measure and record electrical activity in the brain through multiple electrodes placed on the scalp. The electrical charges are then amplified and appear as a graph on a screen. On the graph, different frequency patterns and brainwave rhythms are recorded. The five main frequencies of EEG signals are delta (0.5-4 Hz), theta (4-7 Hz), alpha (8-12 Hz), sigma (12-16 Hz), and beta (13-30 Hz) (Nayak 2020). Any abnormalities in these frequency patterns can help detect and diagnose

various neurological disorders and diseases such as Alzheimer's disease, epilepsy, and pain, Parkinson's disease (PD). Figure 2 illustrates the procedure to detect seizure through EEG, (Shoka 2022).

Alzheimer's disease (AD) is a brain disorder that affects memory and thinking skills, progressively impairing cognitive functions over time (National Institute of Aging). AD can be characterized by amyloid plaques and neurofibrillary tangles in the brain (National Institute of Aging). Initial damage occurs in the brain regions of the entorhinal cortex and hippocampus, which then spreads to areas responsible for language, reasoning, and social behavior, ultimately affecting various regions throughout the brain (National Institute of Aging).

Epilepsy is a chronic brain disorder where neurons sometimes send incorrect signals, causing seizures (National Institute of Neurological Disorders and Stroke). During a seizure, excess electrical activity can lead to involuntary movements, sensations, emotions, and temporary loss of awareness. Recovery times vary, with some people feeling normal immediately after and others taking longer. Seizures can range from convulsions and loss of consciousness to brief lapses in awareness.

While both brain diseases, AD and PD can cause dementia, Alzheimer's primarily affects memory, whereas Parkinson's mainly impacts movement. PD causes uncontrollable movements like shaking, stiffness, and difficulty balancing (National Institute on Aging. "Parkinson's Disease…"). PD arises when the nerve cells in the basal ganglia, a brain region that controls movement, die. As these nerve cells die, less dopamine is released, affecting movement (National Institute on Aging. "Parkinson's Disease…").

Acute and chronic pain are common experiences. Acute pain is sudden and usually results from an injury or trauma, affecting bones, joints, muscles, or nerves. When we feel pain, affected nerves send electrical signals to the brain, where receptors interpret these signals as pain. However, chronic pain is persistent after an injury is healed. Chronic pain lasts three months or longer and can greatly affect emotional and physical health (Watson, 2017). People who are diagnosed with chronic pain can have symptoms beyond pain such as depression and anxiety. This happens after injuries such as broken bones, arthritis or joint problems, repetitive stress injuries, and many more.

Combining acupuncture and EEG can lead to significant health improvements. Acupuncture, a traditional Chinese medicine practice, involves inserting thin needles into specific points on the body to alleviate pain and promote healing. EEG measures brain wave activity to monitor and manage neurological conditions. Together, these practices can enhance physical and mental well-being by reducing pain, improving sleep, and increasing relaxation. The usage of these two practices has proven to have significant effects on patients.

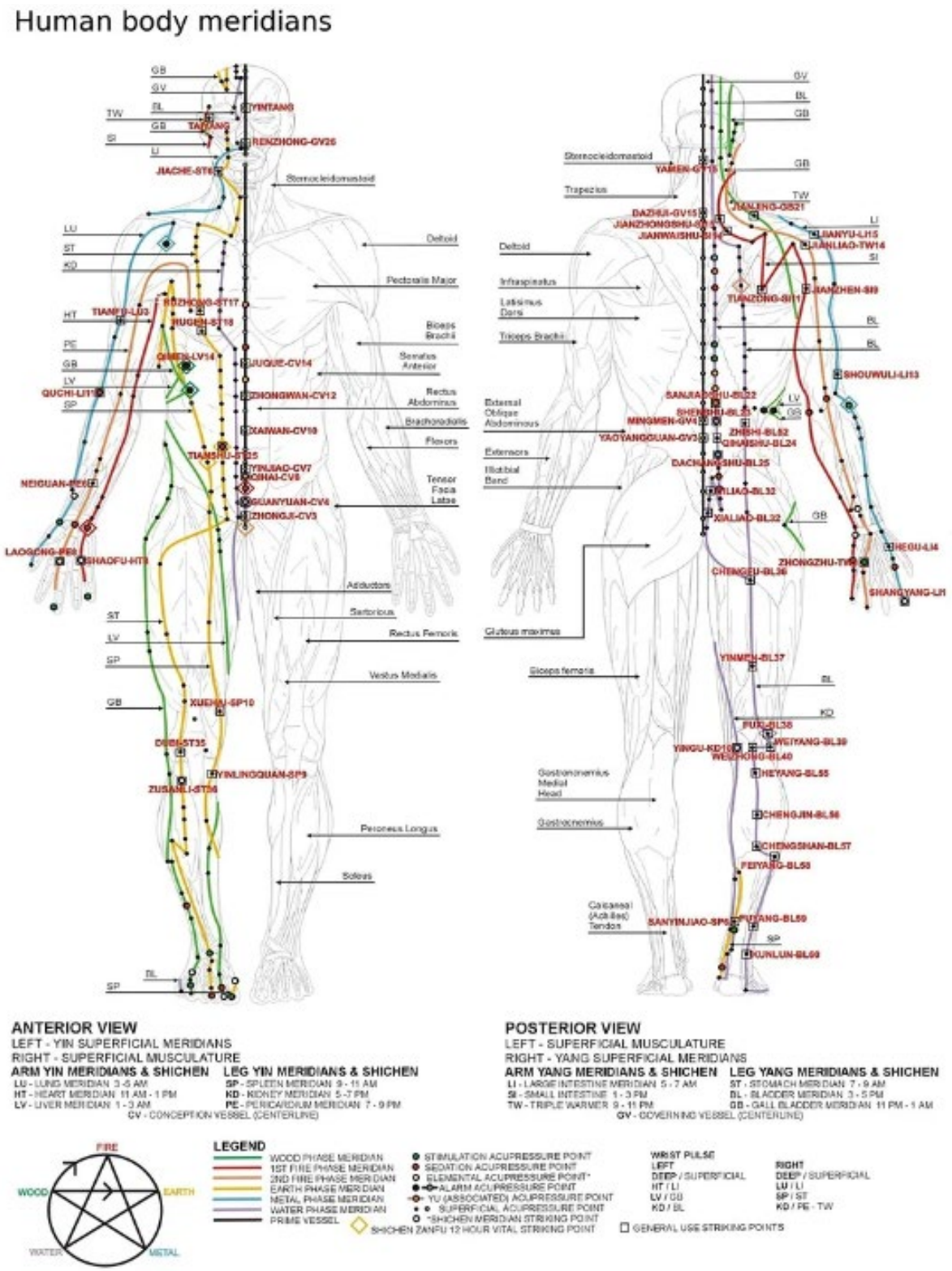

Figure 1..The common acupoints used in different parts of the body ("Understanding the Body Meridians"). In traditional Chinese medicine, meridians are channels in the body that are believed to carry vital energy, or qi, and acupuncture is a practice that involves stimulating specific points along these meridians.

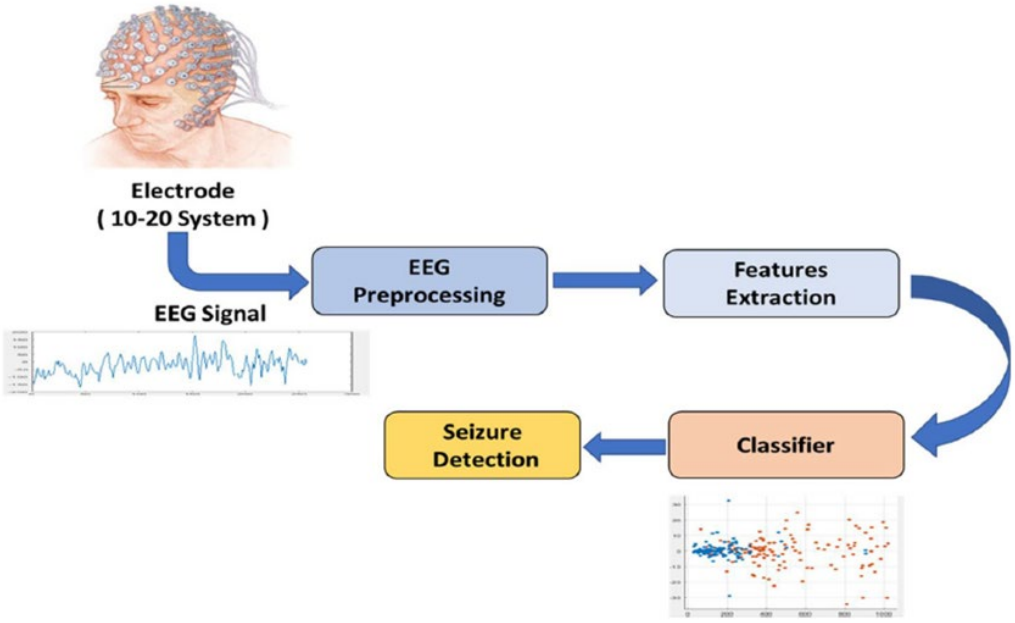

Figure 2. Illustration of the procedure to detect seizure through EEG signals, (Shoka 2022).

Results

Acupuncture and EEG's Impact on Alzheimer's Disease

Acupuncture and EEG have demonstrated beneficial effects on Alzheimer's disease (AD). In a study, patients with AD in a control group were attended with therapy, oral donepezil hydrochloride, and conventional acupuncture (Wu 2023). They found out that acupoints GV20 (top of the head), EX-HN1 (1 cm next to GV20 located on the vertex of the head), EX-HN3 (center of forehead), GV24 (center line of forehead), KI3 (inner ankle), and GB39 (above the ankle joint), have shown improved cognition and memory (Wu 2023) (Table 1 and Figure 3). This suggests that targeted acupuncture may have a therapeutic effect on the brains of Alzheimer's patients. Another form of acupuncture, electroacupuncture can also improve cognitive impairment. Specifically, when EA is used at acupoints Baihui (GV-20) and Shenshu (BL 23), it results in enhanced memory (Yu 2018) (Table 1). This once again proves that targeting specific acupoints is promising to improve memory. Another study conducted that using laser acupuncture can improve cognitive impairment induced by cerebral ischemia. The study demonstrated genes expressed in the brain, CREB, BDNF, Bcl2, and Bax have shown neuroprotective effects (Wu 2023). This finding suggests that laser acupuncture not only aids in cognitive recovery but also modulates key genes involved in neuronal survival.

There is increasing evidence that certain EEG patterns are linked to Alzheimer's Disease (AD), and these patterns might help create early-stage markers for detecting the disease (Horvath et al., 2018; Poil et al., 2013; Rossini et al., 2020; Tait et al., 2020). The most common finding comes from analyzing the EEG signal, which is divided into different frequency bands, including delta (1–4 Hz), theta (4–8 Hz), alpha (8–12 Hz), beta (15–30 Hz), and gamma (30–90 Hz). Many studies have shown that EEG signals in AD patients tend to 'slow down' compared to healthy people. This slowing down is seen through an increase in lower frequencies (delta and theta) and a decrease in higher frequencies (alpha and beta), along with a reduction in the peak alpha frequency (Besthorn et al., 1997; Dauwels et al., 2010; Babiloni et al., 2004; Benwell et al., 2020; Brenner et al., 1986; Meghdadi et al., 2021; Neto et al., 2016; Schreiter-Gasser et al., 1994; Tait et al., 2019). In another study, EEG showed signs that AD could be detected via

periodic changes, not aperiodic ones (Kopčanová 2023). In Alzheimer's disease (AD), changes occur in regular cycles, characterized by reduced oscillatory strength in alpha and beta frequencies compared to healthy controls. This results in lower ratios of combined alpha and beta power relative to delta and theta power in AD patients.

Table 1. Acupuncture treatments for Alzheimer's disease

Author	Number of volunteers	Acupoints	Stimulation	Results
Yu (2018)	n/a	(GV20),(EX-HN 1), (HT 7), (ST 36), (PC 6), (GB 20),(KI 3), (GV 14), (BL 23), (SP 6), (GV 24), (ST 40),(GB 39),(GV 26), (LR 3)	Acupuncture or EA	Enhanced memory mostly used points are: Fengchi (GB 20)-Baihui (GV 20), followed by combinations of Dazhui (GV 14)-Baihui (GV 20), Shenshu (BL 23)- Baihui (GV 20) and Neiguan (PC 6)- Baihui (GV 20)
Liu (2023)	Rats	GV20, GV14	Acupuncture or LA	Improvements in cognitive function
Kopčanová, et al (2023)	45	n/a	n/a	Resting-state EEG in AD shows periodic changes, not aperiodic ones.
Li (2021)	2 rats	DU20, BL23	EA	high-frequency electroacupuncture may enhance hippocampal synaptic transmission and potentially improve memory disorders

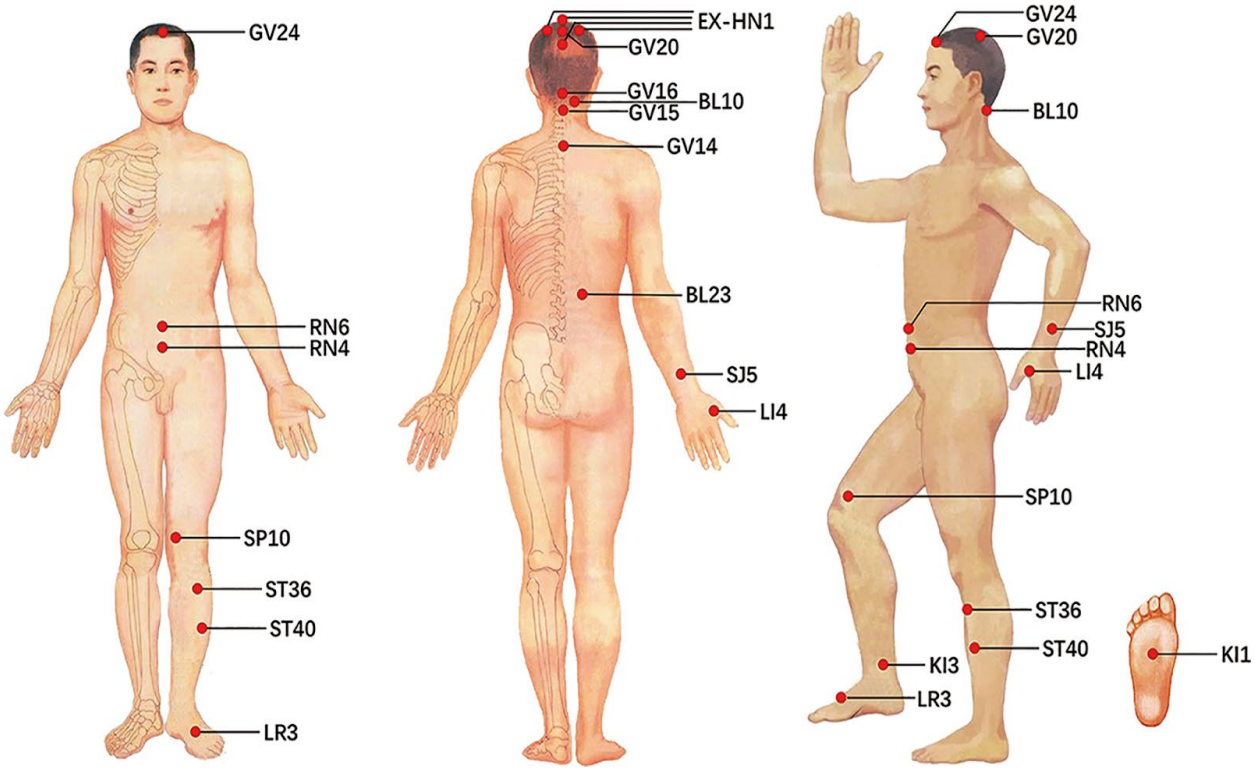

Figure 3. Locations of acupoints selected for the studies by (Yin 2021) in the treatment of Alzheimer's disease.

Acupuncture and EEG in Epilepsy Management

Acupuncture has been shown to decrease the frequency of epileptic episodes, and EEG can predict their occurrence. Transcutaneous auricular vagus nerve stimulation (ta-VNS) has emerged as a promising therapeutic approach for managing epilepsy, similar in concept to electroacupuncture. Ta-VNS and electroacupuncture are similar as both use electrical stimulation to influence the nervous system and to achieve therapeutic effects. In a study involving 47 patients with refractory epilepsy, ta-VNS demonstrated significant improvements (Chen 2014). Many of these patients experienced a noticeable reduction in seizure frequency or even achieved seizure recovery (Table 2). This underscores the potential of ta-VNS as an effective treatment option for epilepsy, offering hope to those who do not respond well to conventional therapies (Chen 2014).

In another investigation by (Guo 2008), the therapeutic effects of electroacupuncture were explored in a rat model of epilepsy. Specifically, EA was applied at acupuncture point ST36 to rats with spontaneous recurrent seizures. The study focused on changes in the expression of GAD (67) mRNA within the brain's dentate gyrus (DG) region, a marker associated with neuronal activity in epilepsy (Table 2). The findings suggested that EA at ST36 could alleviate epileptic symptoms by influencing GAD (67) mRNA levels in the dentate gyrus, highlighting a possible mechanism through which acupuncture may exert its therapeutic benefits in epilepsy (Guo 2008).

Traditional acupuncture was used on 120 patients in the following acupoints: RN15 (Jiuwei), one cun below the xiphisternal junction on the midline; PC5 (Jianshi), three cun above the wrist crease between the tendons; SI3 (Houxi), on the hand near the ulnar side of the fifth knuckle; and ST40 (Fenglong), eight cun above the lateral ankle on the anterolateral leg (Zhang, Yang, et al) (Figure 4). The results demonstrated that after a twelve-month follow-up, patients could be seizure-free.

A study involving eight dogs implanted with mobile intracranial EEG devices found that comparing the spectral power of EEG features indicates that both correlation and spectral power are valuable for predicting seizures

(Brinkmann 2015) (Table 2). Note that acupoint DU14 refers to three points: GV14, LI14, and CV14. For people with epilepsy, the EEG between seizures can reveal one-sided spikes or sharp waves, showing that there's epilepsy activity. The different frequency components from EEG signals to reveal signs of epilepsy are Delta ($f \leq 3$ Hz), Theta ($3.5 \text{ Hz} \leq f \leq 13\text{Hz}$), Beta ($13 \text{ Hz} < f \leq 26\text{Hz}$), and Gamma ($26 \text{ Hz} < f \leq 100$ Hz). (G. Yogarajan 2023) This means that spotting whether the EEG signals are symmetrical or not can help doctors diagnose and treat epilepsy better (G. Yogarajan, 2023). The detection of seizures using EEG is a prominent research area. Shoka (2023) has documented over 60 studies that have achieved accuracies exceeding 90%, utilizing various features and classification methods. Depending on the balance between computational load, accuracy, and algorithmic complexity, alternative algorithms may be employed.

Table 2. Acupuncture applied to Epilepsy

Author	Number of volunteers	Acupoints	Stimulation	Results
Rong (2014)	47	ST36, GV14	EA and ta-VNS	Reduction in seizures
Guo et al. (Oct 2007)	Rats	ST36, DU14, Du20	EA	Positively influenced GAD (67) mRNA levels
Brinkmann, et al. (2015)	8 Dogs	n/a	n/a	Could predict epileptic episodes
G. Yogarajan, et al (2023)	Open source Bonn EEG dataset	n/a	n/a	Could recognize epilepsy from normal activity 100%.
Zhang, et al (2021)	120	RN15, PC5, SI3, ST40	Acupuncture	12-month follow-up without seizures

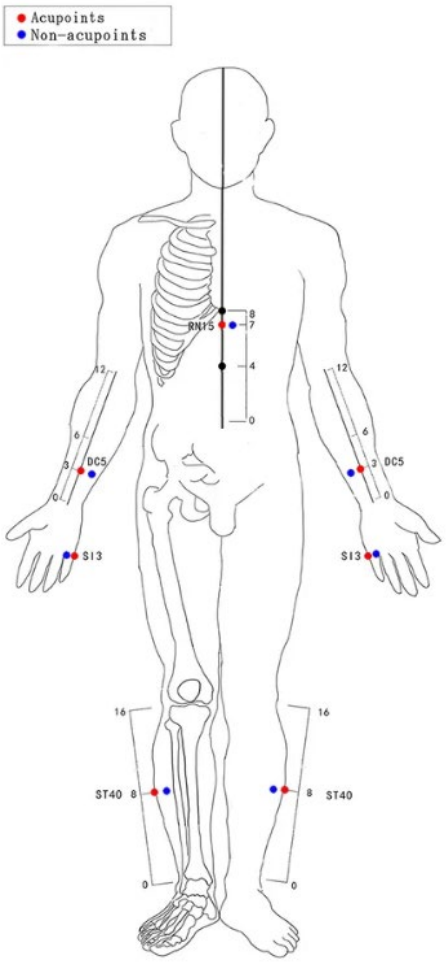

Figure 4. Acupoints and non-acupoints reported in the study by Zhang 2021 in treating Epilepsy

Acupuncture and EEG for Chronic and Acute Pain

Acupuncture has shown promising results in alleviating chronic pain among cancer survivors and other patients (Table 3). In a study, cancer survivors with chronic pain experienced significant relief from electroacupuncture, which reduced pain severity by 1.9 points on the Brief Pain Inventory (BPI). Additionally, auricular acupuncture resulted in a 1.6-point reduction in pain severity (NCI 2021). For patients with chronic pain, acupuncture provided notable pain reduction, with scores of 0.23 (95% C.I. 0.13, 0.33), 0.16 (95% C.I. 0.07, 0.25), and 0.15 (95% C.I. 0.07, 0.24) standard deviations lower than those observed in the controls for back and neck pain, osteoarthritis, and chronic headaches (Vickers 2012). When compared to no acupuncture controls, the effect sizes were 0.55 (95% C.I. 0.51, 0.58), 0.57 (95% C.I. 0.50, 0.64), and 0.42 (95% C.I. 0.37, 0.46) (Vickers 2012). Common local acupoints are chosen where patients feel the most intense pain, such as Yuyao (Ex-HN 4), Cuanzhu (BL 2), and Yangbai (GB 14) for trigeminal neuralgia, or Dachangshu (BL 25) and Guanyuanshu (BL 26) for radiculalgia (lumbar) (Ma, Xin and Figure 5). Regional and distal points, like Quanliao (SI 18), Sibai (ST 2), Juliao (ST 3), Xiaguan (ST 7), Jiache (ST 6), Huantiao (GB 30), Fengshi (GB 31), Xiyangguan (GB 33), Yanglingquan (GB 34), Xuanzhong (GB 39), Zhibian (BL 54), Chengfu (BL 36), Weizhong (BL 40), Chengshan (BL 57), Kunlun (BL 60), Neiting (ST 44), Hegu 4 (LI 4), and Sanjian (LI 3), are selected based on meridian paths or nerve distribution by traditional Chinese medicine (TCM). These acupoints may alleviate pain through the somatosensory system, benefiting patients.

The body's reaction to acupuncture has been shown to have anesthetic effects. Shen suggested that by using the rat model in different frequencies, the rats will induce different levels of analgesia when electroacupuncture is used (Shen, 2001). Electric stimulation is more effective in bursty repetitions than in a constant frequency (Cazalis et al., 1985). Both high-frequency and low-frequency stimulations can reduce or increase cortical excitation to induce analgesia. Still, low and high-frequency acupuncture have differential effects on the endorphins released (Shen, 2001). Low-frequency (2 Hz) and high-frequency (100 Hz) electroacupuncture (EA) selectively induced the release of enkephalins and dynorphins, an opioid peptide, in both animals and humans (Ulett et al., 1998). Additionally, Willer et al. (1982) demonstrated with different frequencies applied to EA, human subjects react differently. Lin et al. (2002) showed that patients required less morphine post-surgically within 24 hours in a high-frequency group than in a low-frequency and sham group, with vomiting and nausea lower in the acupuncture group than in the sham and control group. Zhang et al. (2003) reported that EA-induced analgesia has a positive correlation with analgesic effects in the contralateral area. Park et al. (2010) studied whether low-frequency electroacupuncture helps reduce pain from cold in rats with nerve damage. They found that this pain relief is likely due to certain receptors in the spinal cord.

Acupuncture is also applied to relieve neuropathic pains (Miranda 2015). To monitor the relief of pain through acupuncture, neurological devices like EEG have been used. Litscher (2006) monitored the EEG signal attached to the forehead while applying acupuncture at the median point of the connecting line between SJ 17 (Yi Feng) and Yi Ming (Ex.7). Different acupuncture locations create distinct, consistent, and measurable effects on entropy values in EEG readings (Litscher 2006).

Table 3. Acupuncture shown to have results through EEG for pain

Author	Number of volunteers	acupoints	Stimulation	EEG used	Number of EEG Channels	EEG feature used	EEG classification method	Results
Chen (2006)	12	LI4	EA	EEG	124			A significant change with high-frequency
Litscher (2006)	9	GV20, Ex 1, Ex 9, He7, Pe6, CV6, St36, Sp6	Manual and laser	EEG	124		S/5 Entropy-Module, M-Entropy	Significant changes at sedative points
Zhang, Ke (2023)	15	LI 11	Manual	EEG	32	Power spectral density and magnitude squared coherence	Graph theory analysis	Reduced the brain network's internal connectivity and information transfer efficiency

Choi (2016)	37	LI 4		EEG	8	Power spectrum analysis	ANOVA	Acupuncture stimulation at locations other than the acupuncture points may cause temporary stress to the body.
Yin 2022	20	ST36, ST40, GB37	Magnetic EA	EEG	64	Phase-locking value, clustering coefficient	ANOVA	ST36 and ST40 have similar effects but GB37 is significantly different
Luo 2010	5	ST36	Manual	EEG	22	Lempel-Ziv complexity analysis	One sample t-test	Acupuncture has a great impact on the forehead region.
Li 2010	9	ST36		EEG	22	Power spectral density	ANOVA	Elevated PSD when stimulated, remarkable effect on the brain

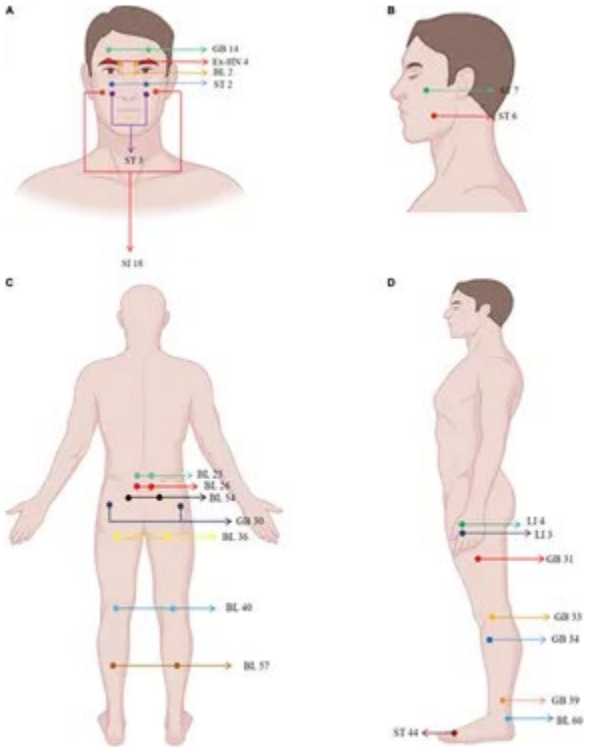

Figure 5. Illustration of prominent acupoint locations, (Ma, 2022) conducted studies on acupuncture parameters and acupoints for the treatment of neuropathic pain.

Acupuncture and EEG can Affect Parkinson's Disease

PD can be influenced by acupuncture and EEG. In the study of PD, acupuncture was tested on various participants, showing different results depending on the acupoints used. One set of acupoints included GB20, LI11, LI10, LI4, GB31, ST32, GB34, and GB38 (Catarina 2022). This approach aimed to help with cognitive, behavioral, and mood issues linked to depression, as well as reduce complications from therapy, lower UPDRS scores, and improve the overall quality of life (Pereira, 2022 and Table 4). Another set, including the foot motor sensory area, balance area, GV20, GV14, LI4, ST36, GB34, BL40, SP6, KI3, and LR3, showed improved walking performance after EA treatment (Table 4). In another test using LR3, SP6, LI4, TE5, HT7, PC6, LI11, and GB20, there were therapeutic benefits for sleep disorders in patients with PD (Table 4 and Figure 6). Acupuncture can also reduce anxiety in Parkinson's patients. Various patients received acupoints, GV 24 (Shen Ting), GV 29 (Yin Tang), bilateral HT7 (Shen Men), bilateral SP 6 (San Yin Jiao), and Si Shen Zhen, which included 4 acupoints, including GV 21, GV 19, and 1.5 cun next to GV 20 bilaterally. This resulted in a significant 7.03-point greater reduction in HAM-A score compared to the sham acupuncture group at follow-up (95% CI, 6.18 to 7.88; $P < .001$) (Fan 2022). A study looked into EEG changes in the early stages of Parkinson's disease (PD) by using wavelet packet analysis and Shannon entropy. They found that EEG signals from PD patients had much higher entropy across the global frequency range, suggesting these signals could be useful as biomarkers for PD (Han 2013). Aljalal (2022) demonstrated a high level of accuracy in detecting Parkinson's Disease (PD) from electroencephalogram (EEG) data by utilizing various entropy measures in conjunction with wavelet transforms and k-nearest neighbors' classification.

Table 4. Acupuncture in treating Parkinson's disease

Author	Number of volunteers	Acupoints	Stimulation	Results
Chen, P-F (2015)	Patient with PD for 6 months	GB20, LI11, LI10, LI4, GB31, ST32, GB34, and GB38	body acupuncture, scalp acupuncture, EA, or auricular acupuncture	- reduce UPDRS scores - improve the quality of life -reduces symptoms and signs of mind, behavior, mood, depression
Lei, H. (2016)	55 years or older with PD	GV20, GV14, LI4, ST36, GB34, BL40, SP6, KI3, LR3	EA	Improved gait parameters
Aroxa (2017)	Ages 35-80	LR3, SP6, LI4, TE5, HT7, PC6, LI11, GB20.	Acupuncture	Improved sleep
(Fan, Jing, et al) (2022)	70 volunteers	GV 24, GV 29, bilateral HT7, bilateral SP6, and Si Shen Zhen, which includes GV 21, GV 19, and points 1.5 cun next to GV 20 bilaterally	Acupuncture	Improved anxiety (HAM-A)

Abbreviations: UPDRS; Unified Parkinson's Disease Rating Scale

Figure 6. Diagram of optimal acupoints for Parkinson's disease (Lei S. 2023)

Discussion and Conclusion

In this study, we investigated the use of EEG (electroencephalography) to assess the effectiveness of acupuncture in treating Alzheimer's disease, managing epilepsy, alleviating pain, and treating Parkinson's disease. We present evidence from various studies that support the efficacy of acupuncture in addressing these conditions.

For Alzheimer's disease, the acupoints GV20 and GV14 have demonstrated effectiveness in rats and humans, making them crucial targets for Alzheimer's treatment (Wu 2023, Yu 2018). Additionally, research by Liang (2014) indicates significant improvements using the acupoints Liv 3 (foot) and Li 4 (hand), further underscoring the potential of these methods. While EEG signals can detect Alzheimer's disease, they may not yet be robust enough for widespread use since a large-scale clinical trial has not been conducted. However, in controlled environments, I believe EEG could be utilized to refine and enhance acupuncture treatments. For instance, EEG could help determine whether additional acupoints would be beneficial, eg. GB 12, GV16 (Wu 2023, Yu 2018).

In epilepsy management, the acupoint GV14 is effective in both rats and humans. (Rong 2014, Guo 2007). Research involving rats, dogs, and other animals is particularly valuable because it allows for a detailed examination of physiological effects, including crucial chemical levels in the body (Guo 2007 Brinkmann 2015). The findings by (Zhang 2021) warrant further attention, as the patient reported being seizure-free for 12 months following acupuncture treatment. While EEG can be used to predict epileptic episodes, it typically requires intrusive implantation (Brinkmann 2015). However, Yogarajan (2023) has reported a high recognition rate for epilepsy using EEG. Given that epileptic episodes are predictable and EEG signals can detect epilepsy with high accuracy, it logically follows that epilepsy is likely to be predictable. Therefore, if a patient wears an EEG sensor, it may be possible to predict the likelihood of the next episode. By integrating this with acupuncture, we could potentially measure whether acupuncture delays the onset of subsequent episodes, suggesting a promising direction for further research.

The acupoint ST36 is widely recognized for its efficacy in providing analgesia and promoting relaxation (Litscher 2006, Yin 2022, Luo 2010, Li 2010). Due to its prominence, researchers can utilize acupuncture at this specific acupoint to monitor changes in EEG signals. This approach allows for the quantification of analgesic effects. Essentially, studies focusing on EEG about acupuncture for pain relief aim to measure the extent of pain alleviation. While EEG changes are easily identifiable in cases of acute pain, assessing the degree of relaxation achieved through acupuncture is more challenging. Nevertheless, it appears feasible by examining EEG signals. Finding an effective method for analgesia through acupuncture is a highly attractive research area. In scenarios such as war zones where analgesic medication may be scarce, acupuncture could serve as an essential pain management tool (NCI 2021).

The articles addressing the treatment of Parkinson's disease with acupuncture generally utilize more than six acupoints. The most commonly employed acupoints include GB20 (Fengchi), LI4 (Hegu), and GB34 (Yanglingquan). Additional acupoints frequently used are GV20 (Baihui), ST36 (Zusanli), LR3 (Taichong), SP6 (Sanyinjiao), GV14 (Dazhui), and LI11 (Quchi). The selection of acupoints varies significantly among researchers, potentially due to the ongoing efforts to determine the most effective treatment approach. Early-stage Parkinson's disease can reportedly be detected through EEG measurements. By utilizing this diagnostic method, it is possible to design experiments aimed at identifying the most effective acupuncture treatment typically at earlier stages. This implies that acupuncture's effectiveness could be monitored by observing shifts in EEG readings toward statistical uncertainty regions. Consequently, EEG could be used to develop more effective acupuncture treatment plans.

In summary, the application of EEG signals in acupuncture treatments holds significant potential to advance the treatment of Alzheimer's disease, epilepsy management, pain alleviation, and Parkinson's disease.

Acknowledgments

I would like to thank my advisor for the valuable insight provided to me on this topic.

References

Racke K et al (1989). Frequency-dependent effects of activation and inhibition of protein kinase C on neurohypophysial release of oxytocin and vasopressin [Journal] Naunyn Schmiedebergs Arch Pharmacol. https://link.springer.com/article/10.1007/BF00168653

Li, Wei, et al. (2016), High-Frequency Electroacupuncture Evidently Reinforces Hippocampal Synaptic Transmission in Alzheimer's Disease Rats. Neural Regeneration Research, vol. 11, no. 5, 1 May 2016, pp. 801–806, www.ncbi.nlm.nih.gov/pmc/articles/PMC4904472/,

Chon, Tony Y., et al. (2019), Laser Acupuncture: A Concise Review. Medical Acupuncture, vol. 31, no. 3, June 2019, pp. 164–168, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6604908

Understanding the Body Meridians (2024), https://www.katokamassagetherapy.com/understanding-body-meridians

Nayak, Chetan S. et al. (2020). EEG Normal Waveforms. PubMed, StatPearls Publishing, 2020. https://www.ncbi.nlm.nih.gov/books/NBK539805/

National Institute on Aging. (2021). What Is Alzheimer's Disease? National Institute on Aging, 8 July 2021, https://www.nia.nih.gov/health/alzheimers-and-dementia/what-alzheimers-disease#:~:text=Alzheimer's%20disease%20is%20a%20brain,appear%20in%20their%20mid%2D60s

National Institute of Neurological Disorders and stroke. (2023). Epilepsy and Seizures | National Institute of Neurological Disorders and Stroke. Www.ninds.nih.gov, 28 Nov. 2023. https://catalog.ninds.nih.gov/sites/default/files/publications/epilepsy-and-seizures.pdf

National Institute on Aging. (2022). Parkinson's Disease: Causes, Symptoms, and Treatments. 14 Apr. 2022, https://www.nia.nih.gov/health/parkinsons-disease/parkinsons-disease-causes-symptoms-and-treatments

UPMC (2024), Acute Pain Causes, Symptoms, and Treatments. https://www.upmc.com/services/pain-management/conditions/acute-pain

Nash (2024), "Acute Pain", progressive pain & rehabilitation, https://drnashcares.com/acute-pain/

Watson, Stephanie (2017). What Is Chronic Pain Syndrome? WebMD, 18 May 2017, www.webmd.com/pain-management/chronic-pain-syndrome-overview

Wu, Liu, et al. (2023), Effect and Mechanism of Acupuncture on Alzheimer's Disease: A Review. Frontiers in Aging Neuroscience, vol. 15, 3 Mar. 2023, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10020224/

Yu, Chaochao et al. (2018). Acupoint Combinations Used for Treatment of Alzheimer's Disease: A Data Mining Analysis. Journal of Traditional Chinese Medicine, vol. 38, no. 6, Dec. 2018, pp. 943–952. https://www.sciencedirect.com/science/article/pii/S0254627218309956

Horvath A. et al. (2018). EEG and ERP biomarkers of Alzheimer's disease: A critical review. *Frontiers in* Bioscience (Landmark Edition), 23(2), 183–220. 10.2741/4587. https://www.imrpress.com/journal/FBL/23/2/10.2741/4587

Poil S.-S. et al. (2013). Integrative EEG biomarkers predict progression to Alzheimer's disease at the MCI stage. Frontiers in Aging Neuroscience, 5. 10.3389/fnagi.2013.00058. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3789214/

Rossini P. M. et al. (2020). Early diagnosis of Alzheimer's disease: The role of biomarkers including advanced EEG signal analysis. Report from the IFCN-sponsored panel of experts. Clinical Neurophysiology, 131(6), 1287–1310. 10.1016/j.clinph.2020.03.003. https://acikerisim.medipol.edu.tr/xmlui/bitstream/handle/20.500.12511/5622/Guntekin,%20Bahar-2020.pdf?sequence=1

Tait L. et al. (2020). EEG microstate complexity for aiding early diagnosis of Alzheimer's disease. Scientific Reports, 10(1), 17627. 10.1038/s41598-020-74790-7. https://www.nature.com/articles/s41598-020-74790-7

Besthorn C. et al. (1997). Discrimination of Alzheimer's disease and normal aging by EEG data. Electroencephalography and Clinical Neurophysiology, 103(2), 241–248. 10.1016/s0013-4694(97)96562-7

Dauwels J. et al. (2010). Diagnosis of Alzheimer's Disease from EEG Signals: Where Are We Standing? Current Alzheimer Research, 7(6), 487–505. 10.2174/156720510792231720

Babiloni C. et al. (2004). Mapping distributed sources of cortical rhythms in mild Alzheimer's disease. A multicentric EEG study. NeuroImage, 22(1), 57–67. 10.1016/j.neuroimage.2003.09.028

Benwell C. S. Y. et al. (2020). EEG spectral power abnormalities and their relationship with cognitive dysfunction in patients with Alzheimer's disease and type 2 diabetes. Neurobiology of Aging, 85, 83–95. 10.1016/j.neurobiolaging.2019.10.004

Brenner R. P. et al. (1986). Computerized EEG spectral analysis in elderly normal, demented and depressed subjects. Electroencephalography and Clinical Neurophysiology, 64(6), 483–492. 10.1016/0013-4694(86)90184-7

Meghdadi A. H. et al. (2021). Resting state EEG biomarkers of cognitive decline associated with Alzheimer's disease and mild cognitive impairment. PLOS ONE, 16(2), e0244180. 10.1371/journal.pone.0244180

Neto E. et al. (2016). Regularized Linear Discriminant Analysis of EEG Features in Dementia Patients. Frontiers in Aging Neuroscience, 8. 10.3389/fnagi.2016.00273

Schreiter-Gasser U. et al. (1994). Quantitative EEG analysis in early onset Alzheimer's disease: Correlations with severity, clinical characteristics, visual EEG and CCT. Electroencephalography and Clinical Neurophysiology, 90(4), 267–272. 10.1016/0013-4694(94)90144-9

Tait L. et al. (2019). Network substrates of cognitive impairment in Alzheimer's Disease. Clinical Neurophysiology, 130(9), 1581–1595. 10.1016/j.clinph.2019.05.027

Kopčanová, Martina, et al. (2023). Resting-State EEG Signatures of Alzheimer's Disease Are Driven by Periodic but Not Aperiodic Changes. BioRxiv (Cold Spring Harbor Laboratory), 12 June 2023, https://doi.org/10.1101/2023.06.11.544491.

Yin, Wei, et al. (2021) Acupuncture Therapy for Alzheimer's Disease: The Effectiveness and Potential Mechanisms. The Anatomical Record, vol. 304, no. 11, 8 Oct. 2021, pp. 2397–2411, https://doi.org/10.1002/ar.24780

Chen, Shuping, et al. (2014). Acupuncture for Refractory Epilepsy: Role of Thalamus. Evidence-Based Complementary and Alternative Medicine, vol. 2014, 2014, pp. 1–8, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4273587/#B7

Guo, Jianjun, et al. (2008). The Effect of Electroacupuncture on Spontaneous Recurrent Seizure and Expression of GAD67 MRNA in Dentate Gyrus in a Rat Model of Epilepsy. Brain Research, vol. 1188, Jan. 2008, pp. 165–172, https://doi.org/10.1016/j.brainres.2007.10.017

Brinkmann, Benjamin H., et al. (2015). Forecasting Seizures Using Bivariate Intracranial EEG Measures and SVM in Naturally Occurring Canine Epilepsy. PLOS ONE, vol. 10, no. 8, 4 Aug. 2015, p. e0133900, https://doi.org/10.1371/journal.pone.0133900.

G. Yogarajan, et al. (2023). EEG-Based Epileptic Seizure Detection Using Binary Dragonfly Algorithm and Deep Neural Network. Scientific Reports, vol. 13, no. 1, 18 Oct. 2023, https://doi.org/10.1038/s41598-023-44318-w

NCI (2021), Can Acupuncture Help Cancer Survivors with Chronic Pain? Www.cancer.gov, 22 Apr. 2021, www.cancer.gov/news-events/cancer-currents-blog/2021/acupuncture-for-pain-cancer-survivors.

Vickers, Andrew J., et al. (2012). Acupuncture for Chronic Pain – individual patient meta-analysis. Archives of Internal Medicine, vol. 172, no. 19, 22 Oct. 2012, p. 1444, https://jamanetwork.com/journals/jamainternalmedicine/article-abstract/1357513

Shen, J. (2001). Research on the neurophysiological mechanisms of acupuncture: review of selected studies and methodological issues. J Altern Complement Med. 2001; 7 Suppl 1:S121-7. https://pubmed.ncbi.nlm.nih.gov/11822627/

Cazalis, M. et al. (1985). The role of patterned burst and interburst interval on the excitation-coupling mechanisms in the isolated rat neural lobe. J. Physiol. (London) 369, 45– 60. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1192635/

Ulett, G.A., Han, S., & Han, J.S. (1998). Electroacupuncture: mechanisms and clinical application. Biol. Psychiatry 44, 129– 138. https://pubmed.ncbi.nlm.nih.gov/9646895/

Willer, J.C. et al (1982). Comparative effects of electroacupuncture and transcutaneous nerve stimulation on the human blink reflex. Pain 14, 267–278. https://pubmed.ncbi.nlm.nih.gov/6984165

Lin, J.G. et al. (2002). The effect of high and low-frequency electroacupuncture in pain after lower abdominal surgery. Pain 99, 509– 514. https://pubmed.ncbi.nlm.nih.gov/12406527/

Zhang, W. et al. (2003). Modulation of pain signal processing by electric acupoint stimulation: an electroencephalogram study. Beijing da Xue Xue Bao. Yi Xue Ban/Journal of Peking University. Health Sciences 35, 236–240.

Park, J.H. et al. (2010). Spinal GABA receptors mediate the suppressive effect of electroacupuncture on cold allodynia in rats. Brain Res. Mar 31; 1322:24-9.

Miranda, J. et al. (2015). Effect of pain chronification and chronic pain on an endogenous pain modulation circuit in rats. Neuroscience 286, 37–44. doi: 10.1016/j.neuroscience.2014.10.049

Litscher, Gerhard, (2006), Electroencephalogram-Entropy and Acupuncture,, Anesthesia & analgesia, international Anesthesia research society. https://journals.lww.com/anesthesia-analgesia/fulltext/2006/06000/electroencephalogram_entropy_and_acupuncture.29.aspx

Ma, Xin, et al.(2022). Potential Mechanisms of Acupuncture for Neuropathic Pain Based on Somatosensory System.Frontiers, 29 Aug. 2022, www.frontiersin.org/journals/neuroscience/articles/10.3389/fnins.2022.940343/full#F2.

Catarina Ramos Pereira, et al. (2022) Effectiveness of Acupuncture in Parkinson's Disease Symptoms—a Systematic Review. Healthcare, vol. 10, no. 11, 21 Nov. 2022, pp. 2334–2334,https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9690518

Fan, Jing, et al. (2022). Effectiveness of Acupuncture for Anxiety among Patients with Parkinson's Disease. JAMA Network Open, vol. 5, no. 9, Sept. 2022, p. e2232133, https://doi.org/10.1001/jamanetworkopen.2022.32133

Han, CX. et al. (2013) Investigation of EEG abnormalities in the early stage of Parkinson's disease. Cogn Neurodyn 7, 351–359 (2013). https://doi.org/10.1007/s11571-013-9247-z

Lei, Suying, et al. (2023). Acupuncture Therapy for Parkinson's Disease: A Case Report Demonstrating Symptomatic Improvement without Medication. Frontiers, 27 Dec. 2023, www.frontiersin.org/journals/neurology/articles/10.3389/fneur.2023.1330054/full

Liang, P. et al. (2014). Acupuncture stimulation of taichong (Liv3) and hegu (LI4) modulates the default mode network activity in Alzheimer's disease. Am. J. Alzheimer's Dis. Other Dementias 29, 739–748. doi: 10.1177/1533317514536600. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10852898/

P. Rong, A. et at. (2014). An alternative therapy for drug-resistant epilepsy: transcutaneous auricular vagus nerve stimulation, Chinese Medical Journal, vol. 127, no. 2, pp. 300–304, 2014

Zhang, Yang, et al. (2021). Acupuncture as an Adjunctive Treatment for Post-Stroke Epilepsy: Protocol for a Randomized Controlled Trial. Frontiers in Neurology, vol. 12, 26 Aug. 2021, https://doi.org/10.3389/fneur.2021.711390

Yin, Ning (2022). Electroencephalogram Analysis of Magnetic Stimulation at Different Acupoints, Ning Yin, 2022, frontiers. https://www.frontiersin.org/journals/neuroscience/articles/10.3389/fnins.2022.848308/full

Luo, Xiliu (2010). Complexity Analysis of EEG Signals Evoked by Acupuncture at 'Zusanli' Acupoint (St36), https://www.researchgate.net/publication/252039403_Complexity_analysis_of_EEG_signals_evoked_by_manual_acupuncture

Li, Nuo. (2010) Analysis of EEG signals during acupuncture using spectral analysis Techniques, automation and logistics, 2010 IEEE International conf. https://www.researchgate.net/publication/224177386_Analysis_of_EEG_signals_during_acupuncture_using_spectral_analysis_techniques

Chen, Andrew C.N.,(2006) Mode and site of acupuncture modulation in the human brain: 3D (124-ch) EEG power spectrum mapping and source imaging. ScienceDirect, 2006. https://www.sciencedirect.com/science/article/abs/pii/S1053811905006245

Zhang, Ke. (2023) Altered brain functional networks after Quchi (LI 11) acupuncture: An EEG analysis, https://www.researchgate.net/publication/370039828_Altered_brain_functional_networks_after_Quchi_LI_11_acupuncture_An_EEG_analysis

Choi, Kwang-Ho,(2016). Evaluating Acupuncture Point and Nonacupuncture Point Stimulation with EEG: A High-Frequency Power Spectrum Analysis, Kwang-Ho Choi, 2016, onlinelibrary.wiley.com https://onlinelibrary.wiley.com/doi/10.1155/2016/2134364

Chen, F.-P.et al. (2015). clinical study of integrating acupuncture andWestern medicine in treating patients with Parkinson's disease. Am. J. Chin. Med. 2015, 43, 407–423. https://www.worldscientific.com/doi/abs/10.1142/S0192415X15500263

Lei, H. et al. (2016). Clinical Trial to Objectively Assess the Efficacy of Electroacupuncture on Gait in Patients with Parkinson's Disease Using Body Worn Sensors. PLoS ONE 2016, 11, e0155613. https://pubmed.ncbi.nlm.nih.gov/27227460/

de Amorim Aroxa, F.H. et al. (2017) Acupuncture as Adjuvant Therapy for Sleep Disorders in Parkinson's Disease. J. Acupunct. Meridian Stud. 2017, 10, 33–38. https://www.sciencedirect.com/science/article/pii/S2005290117300018?via%3Dihub

Aljalal, Majid, et al. (2022) Detection of Parkinson's Disease from EEG Signals Using Discrete Wavelet Transform, Different Entropy Measures, and Machine Learning Techniques. ,scientific reports. Vol. 12, no. 1, 29 Dec. 2022. https://www.nature.com/articles/s41598-022-26644-7

Shoka, Athar A. Ein (2023), EEG seizure detection: concepts, techniques, challenges, and future trends, 2023 multimedia tools and applications, https://doi.org/10.1007/s11042-023-15052-2