Electroencephalogram Brain Connectome: An Approach in Research to Identify the Effect of Acupuncture on Human Brain Wave

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Abstract

Acupuncture has been used for 1000 years, but how it gives therapeutic effect is not completely understood. Integration of brain wave as the central nervous system plays an important role in acupuncture efficacy. To explore the effect of acupuncture stimulation in the central nervous system, it is imperative to decide the adjustments in brain waves that produced because of acupuncture stimulation. Electroencephalogram (EEG) is often used in the acupuncture research area. EEG records spontaneous cerebral activity after some time by positioning electrodes on scalp surface. Using EEG, we can observe the brain connectivity regarding the acupuncture stimulation. An overview regarding the effect of manual acupuncture on human brain wave through EEG observation will be discussed in this review.

Keywords: Acupuncture, brain waves, electroencephalography

Introduction

As one of the Chinese Medicine, acupuncture has been widely used in worldwide, particularly since 1970s. The World Health Organization (WHO) has been conducted a review and analysis of controlled clinical trials on acupuncture to list diseases or disorders in which acupuncture has been tested. There is a wide variety of disorders that can be treated by acupuncture including cardiovascular, psychiatric diseases, chronic and acute pain. Although acupuncture has been used for thousands of years, the mechanism of its therapeutic effect is not completely understood. There is a close relationship between the location of the acupuncture points and the receptors that located around it. When the acupuncture needles are inserted to the body, it stimulates pain receptors (nerve endings) around the skin. It will create many responses from various systems in the body, especially the nervous system.[1] Integration of brain as the central nervous system plays an important role in acupuncture efficacy. The use of electroencephalogram (EEG) as neuroimaging technique can explore the brain connectome before, during, and after acupuncture stimulation. In the discussion chapter, the effect of acupuncture stimulation in human brain wave will be elaborate more.

The Connectomics

The human connectome is a comprehensive map of the brain’s circuitry which consists of brain areas, their structural connections, and their functional interactions. The connectivity can be measured with a variety of different imaging technique.[2] These include principally imaging studies and neurophysiologic measurement (EEG).[3] Connectomics is a...
field that has been developing for concentrate the structure work relationship of connectomes among numbers of neuronal components at all levels from little microcircuits to cortical segment than to bigger area in the brain.\[^4\]

The chief objective of connectomics is the thorough mapping and examination of brain connectivity, overall scales from the small size of individual synaptic associations between neurons to the large scale of brain regions and interregional pathways. The two fundamental procedures for estimating regional brain associations are strikingly unique both in what they endeavor to gauge (structural versus functional connections) and how they measure it. Far-reaching maps of the structural and functional connectivity of the human brain have given essential bits of knowledge into how anatomical association establishes brain dynamics and how this relationship varies across individuals.\[^5\]

**Electroencephalogram and Brain Waves**

Electrical recordings acquired from the external surface of the head demonstrate a constant electrical activity. These electrical signs are recorded by electroencephalography (EEG) as brain waves. EEG signals are liable to noise, therefore, the extraction of information from EEG in this way is a great degree testing. Both power and the pattern of this electrical activity are dictated by the level of excitation of various parts of the brain that cause sleep or brain disorders, for example, epilepsy or mental issues such as anxiety or depression. The character of the wave relies upon the activity level in respective parts of the cerebral cortex and the waves change, particularly between the conditions of alertness, sleep, and coma.\[^6\]

Waves in EEG can be named as alpha (\(\alpha\)), beta (\(\beta\)), theta (\(\theta\)), and delta (\(\delta\)) waves. Alpha waves regularly observed at frequencies between 8 and 13 Hz bandwidth and are found in the EEG of almost healthy adults when they are alert and not concentrating anything in resting position. It usually found over the occipital region of the brain. Most persons create some alpha waves when their eyes closed, and these waves are omitted by opening the eyes, hearing unfamiliar sounds, anxiety, concentration, or attention.\[^7\]\(^\text{[7]}\)

Theta waves regularly observed at frequencies 14 to 30 Hz bandwidth in the active state and when the individual alert. Beta waves found over frontal and central regions of the brain and characterized by low amplitudes.\[^7\]\(^\text{[7]}\)

Delta waves have frequencies between 4 and 7.5 Hz bandwidth. Theta wave is normally enhanced by hyperventilation, drowsiness, and sleep. Delta waves include all the waves of the EEG with frequencies 0.5–4 Hz. They occur in very deep sleep but may be present in the waking state.\[^6\]\(^\text{[6]}\)

**Methods**

There are many publications investigating the changes in EEG occurred by acupuncture application. Identification of research used a standardized format and keywords associated with acupuncture and EEG. The result from the first phase of searching was 344 articles. After obtaining them, limitation 1 can be started which was only the article that appeared in the past 10 years from 2007 to 2017 that will be reviewed. The result of these limitations was 166 articles. Furthermore, among 166 articles, only 145 articles that used English language and after further limitation, only 142 articles that completed by the abstract. Following 142 articles, the new inclusion and exclusion criteria can be used as in Table 1.

**Results**

**Searching result**

Through primary screening, 142 studies were obtained from online database and matched with exclusion and inclusion criteria in Table 1. Some studies exclude because they were animal tested (\(n = 12\)), were review articles (\(n = 8\)), were case reports (\(n = 1\)), were used acupressure (\(n = 1\)), were used acupuncture (\(n = 1\)), were used transcutaneous acupoints electrical stimulation (\(n = 7\)), were used electroacupuncture (\(n = 5\)), were used laser acupuncture (\(n = 1\)), were used acupuncture point magnet therapy (\(n = 5\)), were used electrical or light beam pulse stimulation to induced pain (\(n = 2\)), were combined acupuncture with another therapy (\(n = 3\)), and the result were not related to brain wave (\(n = 78\)). Finally, 19 studies matched our study criteria and were included in this systematic review [Table 2].

**Subject of the studies**

Based on 19 trials in our systematic review, 17 trials used healthy subject,\[^9,21\]\(^\text{[9,21]}\) one trial used chronic pancreatitis patients (\(n = 15\)),\[^20\]\(^\text{[20]}\) and one trial used chronic pain patients (\(n = 76\)).\[^27\]\(^\text{[27]}\)

**Study design**

Among 19 studies that being reviewed, thirteen articles were quasi-experimental;\[^9,10,12,14,16,18,21,23,25,27\] \[^9,10,12,14,16,18,21,23,25,27\] meanwhile, the others used were single-blind randomized crossover study,\[^11\]\(^\text{[11]}\) randomized clinical trial (RCT) parallel group,\[^13\]\(^\text{[13]}\) randomized single-blinded crossover pilot study,\[^19\]\(^\text{[19]}\) randomized blinded parallel group study,\[^20\]\(^\text{[20]}\) randomized single-blinded prospective crossover study,\[^26\]\(^\text{[26]}\) and randomized double-blind crossover design.\[^22\]\(^\text{[22]}\)

<table>
<thead>
<tr>
<th>Table 1: Criteria of exclusion and inclusion article</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exclusion criteria</strong></td>
</tr>
<tr>
<td>The research will include the category of exclusion if the study emphasizes more on/specifically discussed/include</td>
</tr>
<tr>
<td>Animal tested</td>
</tr>
<tr>
<td>Review, case report</td>
</tr>
<tr>
<td>Used acupressure TAES, electroacupuncture, laser acupuncture, acumagnet therapy</td>
</tr>
<tr>
<td>Used electrical or light beam pulse stimulation to induced pain</td>
</tr>
<tr>
<td>Acupuncture combines with another therapy (moxibustion)</td>
</tr>
<tr>
<td>Result not relevant to brain wave</td>
</tr>
</tbody>
</table>

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## Table 2: Studies on acupuncture and electroencephalogram

<table>
<thead>
<tr>
<th>Author</th>
<th>Design</th>
<th>Participant</th>
<th>Sample size</th>
<th>Intervention type and EEG channel</th>
<th>Points</th>
<th>Control</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sakai et al., 2007</td>
<td>Quasi-experimental</td>
<td>HS</td>
<td>16</td>
<td>MA 19-channel EEG</td>
<td>Acupoint at right trapezius muscle (before needle insertion)</td>
<td>Sham acupuncture</td>
<td>Acupuncture manipulation nonspecifically increased the power of α, β, and θ spectral bands except γ</td>
</tr>
<tr>
<td>Hsu et al., 2007</td>
<td>Quasi-experimental</td>
<td>HS</td>
<td>10</td>
<td>MA NA</td>
<td>Sishenchong, auricular acupuncture at Shennong LI4</td>
<td>Sham acupuncture</td>
<td>The power of low-frequency band (below 13 Hz) of EEG was increased after scalp or auricular acupuncture</td>
</tr>
<tr>
<td>Streitberger et al., 2008</td>
<td>A single-blind randomized crossover study</td>
<td>HS</td>
<td>20</td>
<td>MA 16-channel EEG</td>
<td>Sham acupuncture</td>
<td>Verum needle stimulation in LI4 significantly (P&lt;0.03) increased the power in the α1 frequency of the occipital region</td>
<td></td>
</tr>
<tr>
<td>Kim et al., 2008</td>
<td>Quasi-experimental</td>
<td>HS</td>
<td>10</td>
<td>MA 16-channel EEG</td>
<td>PC 6</td>
<td>Sham acupuncture</td>
<td>EEG power increased after acupuncture stimulation in all frequency bands (α, β, θ, and δ waves)</td>
</tr>
<tr>
<td>Chang et al., 2009</td>
<td>Quasi-experimental</td>
<td>HS</td>
<td>12 (6/6)</td>
<td>MA 12-channel EEG</td>
<td>PC 6</td>
<td>Sham acupuncture</td>
<td>Amplitude and power of α band increase during manual acupuncture (P&lt;0.05)</td>
</tr>
<tr>
<td>Yin et al., 2010</td>
<td>Quasi-experimental</td>
<td>HS</td>
<td>10</td>
<td>MA 32-channel EEG</td>
<td>LI4</td>
<td>Baseline data (before needle insertion)</td>
<td>Subject to higher ratings of needle retention sensation showed a significant change in α band power before, during, and after needle retention</td>
</tr>
<tr>
<td>Hsu et al., 2011</td>
<td>Randomized clinical trial</td>
<td>HS</td>
<td>24 (12/12)</td>
<td>MA 19-channel EEG</td>
<td>SJ 5</td>
<td>Sham acupuncture</td>
<td>During acupuncture stimulation, α and θ energy is increased and had statistical differences</td>
</tr>
<tr>
<td>Yi et al., 2013</td>
<td>Quasi-experimental</td>
<td>HS</td>
<td>8</td>
<td>MA 20-channel EEG</td>
<td>ST 36</td>
<td>Baseline data (before needle insertion)</td>
<td>The complexity of δ rhythm during acupuncture is lower than before acupuncture while the complexity of α rhythm is higher than before acupuncture. No obvious change in complexity of θ, γ, β rhythms</td>
</tr>
<tr>
<td>Pei et al., 2014</td>
<td>Quasi-experimental</td>
<td>HS</td>
<td>15</td>
<td>MA 19-channel EEG</td>
<td>ST 36</td>
<td>Needle kept in resting state without manipulation</td>
<td>Manual acupuncture can influence the complexity of EEG subbands in different ways and lead to the functional brain networks to obtain higher efficiency</td>
</tr>
<tr>
<td>Tian et al., 2014</td>
<td>Quasi-experimental</td>
<td>HS</td>
<td>30</td>
<td>MA after de qi 12-channel EEG</td>
<td>ST 36, LI 4</td>
<td>Needle kept in resting state without manipulation</td>
<td>No remarkable change was seen in EEG. In different brain region, the change of EEG before and after de qi was not evident</td>
</tr>
<tr>
<td>Juel et al., 2015</td>
<td>Randomized single-blinded crossover study</td>
<td>HS</td>
<td>15</td>
<td>MA 64-channel EEG</td>
<td>ST 25, ST 26, CV 4, CV 6, CV 7, CV 9, CV 10, CV 12, LI 4, ST 37</td>
<td>A nonpenetrating sham device on acupoint</td>
<td>No differences in EEG spectral power distribution between sham and acupuncture were seen (all P&gt;0.6).</td>
</tr>
<tr>
<td>Nierhaus et al., 2015</td>
<td>Blinded study</td>
<td>HS</td>
<td>23</td>
<td>MA 32-channel EEG</td>
<td>ST 36</td>
<td>Sham acupuncture</td>
<td>EEG result, mu rhythm power was significantly enhanced after stimulation of ST 36</td>
</tr>
<tr>
<td>Acker et al., 2015</td>
<td>Quasi-experimental</td>
<td>Burnout syndrome and chronic pain patients</td>
<td>10 burn out syndrome, 38 chronic pain</td>
<td>MA NA</td>
<td>LI 4, LI 11, ST 36, SP 6, LV 3</td>
<td>1-1.5 years without acupuncture treatment</td>
<td>Positive mood scales found after 10 acupuncture treatment, it correlated to the decrease of EEG wave amplitude. Needle rotation seems to be the key physiological parameter to facilitate the acupoint brain interaction</td>
</tr>
</tbody>
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Table 2: Contd...

<table>
<thead>
<tr>
<th>Author</th>
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<th>Points</th>
<th>Control</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choi et al., 2016[23]</td>
<td>Quasi-experimental</td>
<td>HS</td>
<td>37</td>
<td>MA 8-channel EEG</td>
<td>LI 4</td>
<td>Sham acupuncture</td>
<td>Nonacupuncture point stimulation increases the absolute power and relative power of high β and γ waves</td>
</tr>
<tr>
<td>Juel et al., 2017[24]</td>
<td>Randomized single-blinded, prospective crossover study</td>
<td>Chronic pancreatitis patients</td>
<td>15</td>
<td>MA 64-channel EEG</td>
<td>CV 12, CV 10, CV 9, CV 6, CV 4, point 0.5 cun left to the CV 9, ST 25, extra point 0.5 cun above right ST 24, SP 15, extra point 4 cun right of the CV 12, extra point 3 cun right of the CV 11</td>
<td>A nonpenetrating sham device on acupoint</td>
<td>No differences in relative EEG spectral power distribution were seen between acupuncture and sham stimulation groups for any of the frequency bands α, β, δ, θ</td>
</tr>
<tr>
<td>Lee et al., 2017[21]</td>
<td>Quasi-experimental</td>
<td>HS</td>
<td>9</td>
<td>MA 19-channel EEG</td>
<td>HT 7</td>
<td>Baseline data (before needle insertion)</td>
<td>In θ-band coherence significantly increase between temporal and occipital area during acupuncture stimulation. In θ-band coherence significantly increase between left temporal area and other areas (frontal, parietal, occipital)</td>
</tr>
<tr>
<td>Hauck et al., 2017[22]</td>
<td>Double-blind crossover design</td>
<td>HS</td>
<td>26</td>
<td>MA 128-channel EEG</td>
<td>LI 11</td>
<td>Sham acupuncture</td>
<td>Gamma oscillations were localized in the PFC, MCC, primary somatosensory cortex and insula</td>
</tr>
<tr>
<td>Yu, 2016[24]</td>
<td>Quasi-experimental</td>
<td>HS</td>
<td>19</td>
<td>MA 19-channel EEG</td>
<td>ST 36</td>
<td>Needle kept in resting state without manipulation</td>
<td>The power spectrum of EEG is significantly increasing in δ and θ, while a decrease in α band. Acupuncture can substantially change the functional connectivity of the brain. The minimum path length is largely decreased and the clustering coefficient keeps increasing during and after acupuncture in δ and θ bands</td>
</tr>
<tr>
<td>Li, 2017[21]</td>
<td>Quasi-experimental</td>
<td>HS</td>
<td>15</td>
<td>MA 20-EEG channels</td>
<td>ST 36</td>
<td>Needle kept in resting state without manipulation</td>
<td>The synchronization of EEG signals and the functional connections between the brain regions are increased during acupuncture. δ and θ bands are affected more obviously by acupuncture than the other subbands</td>
</tr>
</tbody>
</table>

MA: Manual acupuncture, HS: Healthy subject, NA: Not available, PFC: Prefrontal cortex, MCC: Mid-cingulated cortex, EEG: Electroencephalogram

**Intervention of acupuncture**

According to the WHO, acupuncture literally means to puncture with a needle. In this review, the term acupuncture is used only to include traditional body needling (manual acupuncture) that only use needle alone on acupuncture point location. Based on 17 trials that used healthy people as the subject, the most common acupuncture points that were selected by the researcher is Hégù (LI 4; 5/17; 29.41%).[11,14,18,19,23] It followed by Zusanlí (ST 36, 6/17, 35.29%)[16-18,20,24,25] and Neiguan (PC 6, 2/17, 11.77%).[12,13] Zusanlí located on the anterior aspect of the leg on the line connecting ST 35 (Dubí) with ST 41 (Jiexí), 3 cun inferior to ST 35. Hégù located on the dorsum of the hand radial to the midpoint of the second metacarpal bone.[28] Those two acupoints were chosen because their easy accessibility of de qi sensation.[18] While 17 out of 19 studies used healthy subject, another 2 studies were used chronic pain patients and chronic pancreatitis patients. Acupoint that was used in chronic pain patients were LI 4 (Hégù), LI 11 (Quchi), ST 36 (Zusanlí), SP 6 (Sanyinjiao), and LV 3 (Taichong).[27] While for chronic pancreatitis patients, the acupoint that chosen were CV 12 (Zhongwan), CV 10 (Xiawan), CV 9 (Shuifén), CV 6 (Qǐhái), CV 4 (Guanyuan), 0.5 cun left of the CV 9, ST 25 (Tianshu), an extra point 0.5 cun above right ST 24 (Huaroumen), SP 15 (Daheng), extra point 4 cun right
of the CV 12 (Zhongwan), and extra point 3 cun right of the CV 11 (Jianli).\[26\]

**Control intervention**

Five trials compared verum acupuncture with baseline data (no treatment),\[9,14,16,21,27\] ten trials compared verum acupuncture and sham acupuncture,\[10-13,15,19,20,22,25\] and four trials compared needle manipulation and needle kept in resting state without manipulation.\[17,18,24,25\]

**Outcome measurement**

The primary outcome was measured by EEG. In some of the studies, they were also used EEG with ECG, blood pressure recorder, pulse recorder, and tonometry. It was because some of the studies not only identify the change of EEG after acupuncture, they also aim to identify the relationship between changes in EEG and sympathetic-parasympathetic autonomic function.\[9,11\] EEG also combined with vivo ultrasonic imaging, laser Doppler perfusion imaging, electromyographic, and functional magnetic resonance imaging in a study that aims to investigate the intrinsic property of de qi and how to evaluate it quantitatively.\[14\] Other studies use EEG and acupuncture sensation questionnaire as a measurement to explore any significant EEG changes in relation to the subjective ratings of acupuncture sensation\[14\] and the last EEG combined with visual analog scale (VAS) to examine the pain-relieving effect of acupuncture compare to sham stimulation.\[19\]

**Electroencephalogram on acupuncture stimulation versus before acupuncture stimulation**

Studies that used before needle insertion stage as control group found that acupuncture stimulation showed an effect on the human brain wave. During acupuncture stimulations and poststimulation, α, β, and θ powers were increased meanwhile there were no significant changes in Y power.\[16\] Acupuncture stimulation with de qi is clinically effective through the central nervous system. It showed by the increasing of phase coherence in θ and α bands during the retention of acupuncture needle after de qi.\[21\] Positive mood scales improvement also found after ten acupuncture treatments. It significantly correlated to the decrease of EEG wave amplitude.\[27\]

Another research that aimed to identify the changes in EEG in relation to subjective ratings of acupuncture sensation found that the group with higher ratings of needle retention sensation based on questionnaire items, showed significant changes in α band EEG power compare to lower rating group.\[14\] Yi et al. reported that the complexity of δ rhythm during acupuncture is lower than before acupuncture while the complexity of δ rhythm is higher than before acupuncture. Furthermore, there was almost no obvious change in complexity of θ, β, and Y rhythms.\[16\]

**Electroencephalogram on verum acupuncture versus sham acupuncture**

The highest EEG amplitude in all lobes was after stimulation of acupuncture points. EEG power increased after acupuncture stimulation in all frequencies band (α-waves, β-waves, θ-waves, and δ-waves).\[12\] Compared to sham acupuncture, verum needle stimulation in LI 4 significantly (P < 0.03) increased the power in the α1 frequency of the occipital region.\[18\] Analysis of EEG signals in manual acupuncture experiments showed that the average logarithmic power and frequencies of the alpha band in the brain activities of each subject were all affected by acupuncture.\[13\] Mu rhythm power on EEG also significantly enhanced after stimulation of verum acupuncture compared to the two control points.\[20\]

The power of low-frequency band (below 13 Hz) of EEG was increased after acupuncture stimulation. It shows that the acupuncture stimulation slows down the activity of the cerebral cortex.\[18\] During the acupuncture stimulation, the θ energy is increased and had statistical differences at all electrode points, T3, T4, O1, and O2. The α-wave also noted to have a statistical difference and it was increased at T3 point.\[15\] Pain-related gamma oscillation in the EEG also more strongly decreased during verum than sham treatment. Gamma oscillations were localized in the insula, primary somatosensory cortex, mid-cingulate cortex (MCC), and the prefrontal cortex. The decrease of pain ratings was remarkably correlated with an increase of connectivity between the insula and MCC.\[22\]

However, there were some of the studies found that there was no change in the human brain after acupuncture stimulation. No differences in EEG spectral power distributions were seen between manual and sham acupuncture (all P > 0.6).\[19\] After acupuncture and sham stimulation, no differences in relative EEG spectral power distribution were seen between groups for any of the frequency bands δ, θ, α, and β. Furthermore, no differences in EEG topographies between groups were evident for any of the frequency bands (all P > 0.6).\[26\]

**Electroencephalogram during acupuncture manipulation versus during needle in resting state without manipulation**

A research conducted by Tian et al. aims to investigate the intrinsic property of de qi, found that no remarkable change was seen in EEG. In different brain regions, the change of EEG before and after de qi was not evident.\[18\] In contrasts with Yu et al. that found during and after acupuncture, the minimum path length is largely decreased in delta and theta bands. It indicated that acupuncture enhances processing and information transmission within different brain areas,\[23\] which is in accordance with Li et al. that found the synchronization of EEG signals and the functional connections between the brain regions are increased during acupuncture. Manual acupuncture can impact the complexity of EEG subbands in various ways and lead the functional brain networks to acquire higher efficiency contrast with preacupuncture control state.\[17\]

**Discussion**

This systematic review elaborates the effect of acupuncture on the brain activity by analyzing the change of EEG signals during and after acupuncture stimulation. As to the temporal impact of acupuncture stimulation, numerous researchers have
shown that acupuncture can prompt sustained impacts in the brain even though after the end of the treatment. Acupuncture point specificity lies at the center of traditional acupuncture theory; the clinical adequacy of acupuncture therapy is said to rely on the particular placement of the needle at designated acupuncture points. The differences in brain responses due to acupuncture stimulation were reported between studies. To get an accurate interpretation of acupuncture actions, it relies upon how successfully we can describe the nature of temporal variations in brain response due to acupuncture stimulation. Variability in needling technique, de qi sensations, the design of the study, differences in neuroimaging hardware and software, and data postprocessing methods are altogether liable to represent differences in brain responses among studies. Therefore, it is essential to characterize a standardized framework for the details of acupuncture manipulation. Furthermore, it is important to enhance and standardize the utilization of sham or control intervention in acupuncture studies.

Among trials comparing verum acupuncture and sham acupuncture, two studies reported that there were no differences in EEG spectral power distribution after verum acupuncture and sham stimulation. There was one similarity that might make both of studies have the same results. These trials used the same procedure in their sham intervention. They applied a sham device (a hollow inner tube with a sharp tip fitted into the central channel of the base) at the exact same acupoint as the acupoint that used in the real intervention. Both of real and sham intervention used same acupoints. Not only used identical acupoints, but they also applied manipulation on needle and sham devices. When they did it on the real location of the acupuncture point, it will make no significant result of EEG compared with verum acupuncture. Even though it did not penetrate the skin or make any abrasion, the patients felt a pricking sensation when the tip of the inner tube touched the skin. This simulated the puncturing sensation on the skin by real acupuncture needle in the real acupuncture point. The use of real acupuncture point and manipulation seems to be the key of physiological activity that facilitates brain interaction due to acupuncture stimulation.

The rest of the studies that used baseline data (no treatment stage); sham acupuncture (nonacupuncture point stimulation); needle in resting state (needling without manipulation) as a control or sham intervention, showed that acupuncture stimulation had an effect on the human brain wave.

Acupuncture studies on healthy participants focus on elaborating acupuncture specificity through assessing some aspects such as the specificity of the acupuncture point, acupuncture sensation, and various responses induced by vary stimulation method. However, due to differences in the design of the study, details of acupuncture point stimulation and small sample size, the findings are varied. Acupuncture give impact on EEG power in different frequency bands. Despite the effect is distinct among different acupuncture point. For instance, acupuncture on LI 4 can increase EEG power of α1; acupuncture on Sishenchong and Shenmen auricular acupoint can increase the power of low-frequency band below 13 Hz; acupuncture on PC 6 can increase power of α, β, θ, and δ band. Besides affect the EEG power, acupuncture stimulation also improve functional brain connectivity and facilitate information transmission. Acupuncture on ST 36 not only increased power spectrum in δ and θ but also increased the synchronizing of EEG signals and the functional connections between the brain regions. Functional regions of brain network become much closer implying an enhancement of information transmission and processing within different brain area.

Another factor that can affect the brain activity during acupuncture is patient experiences of acupuncture sensation. A study found that the group with higher ratings of needle sensation showed a significant change in α band power before, during and after needle retention. It can conclude that needle sensation in some subjects may closely relate to brain activity.

Besides those aspects, different analysis methods that have been used in acupuncture studies also plays a role in making the result of the studies differ from one to another. Pei et al. and Yi et al. conducted a research used healthy subjects who undergo acupuncture at ST 36. One research that used wavelet limited penetrable visibility graph approach to analyze EEG data found that manual acupuncture can influence the complexity of EEG subbands in different ways and lead to the functional brain networks to obtain higher efficiency compared with the preacupuncture control state. Meanwhile, another research used an order recurrence quantification analysis combined with discrete wavelet transforms to analyze dynamic of EEG rhythms, found that complexity of δ rhythm during acupuncture decreased while the complexity of α rhythm during acupuncture increased. No obvious change in complexity of θ, Y, and β rhythms relative to preacupuncture state.

EEG is able to provide precise temporal dynamic information regarding the effect of acupuncture. However, the conclusions of these studies are varied. The differences of acupuncture point stimulation, type of stimulation, and experimental design contribute to the unconformity.

**Limitation and Future Direction of Studies**

Limitation of the current studies is as follows: (1) Most of the studies use healthy people as their subjects, only two researchers that used patients. As we know acupuncture is complementary and alternative medicine. There should be more research that focuses on the pathological condition in order to observe whether acupuncture treatment significant or not in improving patient condition. The change of EEG after acupuncture stimulation provides a useful rationale for the interactions of disease-specific neural correlates and acupuncture targeted regulatory encoding in the brain. Using sick people as their subject, it will give us a clear evidence to determine acupuncture therapeutic effect. Therefore, the study on patients is more important to identify the therapeutic mechanism of acupuncture; (2) the second
limitation is related to study design. Most of the studies applied the quasi-experimental design and only six studies applied RCTs. RCT employ randomization to control the effects of variables meanwhile quasi-experimental design provides a less satisfactory degree of control and only used when randomization is not feasible. Moreover, most of the studies focused on the immediate effect of acupuncture stimulation. In order to know the significance of a treatment, long-term effect observation more important than immediate effect. At the end, investigation of the sustain effect of acupuncture stimulation to patients should be implemented in the future study.

**CONCLUSION**

To understand the action of acupuncture practice in the central nervous system, it is essential to determine the changes in brain waves that appeared because of acupuncture stimulation. Acupuncture stimulation has an effect on the human brain wave. Its stimulation passes through the central nervous system and causes some changing in certain brain wave. Alpha bands are the most frequent brain wave that significantly affected by this stimulation. Acupuncture stimulation might cause relaxation and might give therapeutic effect. However, because of the lack of high-quality RCT’s further evidence, the conclusion of this review is limited.

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**Conflicts of interest**

There are no conflicts of interest.

**REFERENCES**