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Original Article
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Acupuncture for Attenuating Frontal Lobe α Band Asymmetry Induced by Anger: a pilot study

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Objectives: Previous studies have shown that anger can lead to frontal lobe α (8-13 Hz) band asymmetry (FAA) in electroencephalogram (EEG), in accordance with motivational direction. This pilot study aimed to investigate the impact of acupuncture on FAA elicited by anger.

Methods: Thirty-four right-handed participants scoring above 75 points on the Novaco Anger Scale were included. Baseline EEG signals were recorded for eight minutes using a 32-channel cap under comfortable conditions. Anger was induced through a nine-minute sequence of Articulated Thoughts in Simulated Situations (ATSS) task. Following that, participants received acupuncture at GB20 and GB21 for 10 minutes. Fast Fourier transform was employed for frequency analysis, and repeated measure ANOVA was conducted for statistical analysis.

Results: The results revealed that participants exhibited significantly higher FAA ($p = 0.026$), particularly in the left hemisphere, after the ATSS task sequence compared to the baseline. During acupuncture treatment, the greater left-sided FAA was significantly reduced ($p = 0.027$) and reversed. Upon the cessation of acupuncture, FAA returned to a value between the baseline and the anger-evoked stage ($p = 0.046$).

Conclusion: The EEG results of this study revealed that anger stimulation induced an increase in left-sided FAA, which was effectively alleviated by acupuncture. This led to an immediate restoration of FAA asymmetry induced by anger. These findings suggest the potential of acupuncture as a treatment option for reducing FAA associated with anger.

Keywords: electroencephalography, brain waves, alpha rhythm, anger, acupuncture

INTRODUCTION

Anger is a fundamental and adaptive emotion, which serves as a coping mechanism for life's challenges. However, inadequate anger control can lead to aggressive behavior, damaged social relationships, and even damaging health conditions such as chronic pain, autonomic nervous system disorders, and mood disorders [1]. Individuals with recurrent anger-related psychosocial difficulties are at risk of developing intermittent explosive or bipolar disorder if appropriate treatment is not administered [2, 3]. Despite the significance of early and proactive intervention, there is currently no standardized treatment for anger control, with the exception of certain medications [4].

Although the neurophysiological mechanisms underlying anger remain unclear, previous research on electroencephalogram (EEG) has suggested potential indicators of anger processing [5]. EEG measurements have shown that anger stimulation induces asymmetrical activity in the alpha band (8-13 Hz) of the frontal cortex. In the context of anger, this frontal lobe alpha band tends to exhibit greater left activity because of the negative

valence associated with approach motivation [6]. According to the behavioral approach system (BAS), negative valence with approach motivation elicits greater activation in the left frontal lobe than positive valence with withdrawal motivational emotions [7].

Acupuncture has been used for various psychiatric disorders, including intermittent explosive disorder and impulse control disorders [8]. Acupuncture modulates the nervous system and induces immediate changes in EEG, allowing for regulation of the emotional state [9, 10]. Furthermore, previous studies have shown that acupuncture treatment leads to real-time changes in EEG, specifically targeting the brain area associated with the corresponding meridian. For instance, the stimulation of acupoints results in instantaneous alterations in brain waves in a specific brain region related to the meridian being treated [11].

EEG analysis presents a promising approach to evaluate the effects of acupuncture treatment on psychiatric disorders, particularly those involving emotional dysregulation. However, only a limited number of studies have investigated the relationship between anger-evoked frontal lobe alpha band asymmetry (FAA) and acupuncture treatment. Therefore, the objective of this study was to explore the feasibility of acupuncture as an intervention for attenuating anger-induced FAA.

MATERIALS AND METHODS

1. Study design

In this experimental pilot study, we aimed to investigate the potential value of acupuncture for alleviating anger-induced FAA. The study adhered to the principles outlined in the Declaration of Helsinki, and the acupuncture treatment procedure was designed and reported following the recommendations of The Standards for Reporting Interventions in Clinical Trials of Acupuncture (STRICTA). Ethical approval for the study was obtained from the Institutional Review Board of Kyung Hee University Korean Medicine Hospital (approval number: KOMCIRB-170717-HR-024).

2. Participants

A total of 34 healthy volunteers were enrolled in this study. The following inclusion criteria were applied: 1) age between 18 and 60 years; 2) right-handedness; 3) screening test (Novaco Anger Scale) score > 75 points; 4) no communication difficulties, including reading and speaking; and 5) written consent obtained from each participant before the procedures. The exclusion criteria included individuals who: 1) expressed fear or apprehension toward manual acupuncture; 2) had received treatment for a psychiatric disorder within the past month; or 3) had participated in another clinical study within the preceding month prior to this study.

3. Screening procedure

The screening procedure involved the use of the Novaco Anger Scale (NAS), a well-established self-report measure that assesses various aspects of anger based on a theoretical model that considers anger as a subjective emotional state accompanied by physiological arousal and cognitive perceptions of antagonism [12]. The NAS is widely recognized and has been empirically validated as a reliable measure of anger [13-15]. In this study, the Korean version of the NAS was used, which consists of a 32-item questionnaire assessing the cognitive and expressive aspects of anger [16]. Each item was rated on a 5-point Likert scale, ranging from 0 ("very little") to 4 ("very much").

The NAS was employed as a screening tool to exclude participants who did not experience sufficient levels of anger during the anger stimuli procedure. It was important to ensure that the participants were adequately motivated by the anger stimuli to avoid excessive baseline heterogeneity. A cutoff criterion score of 75 points, representing the top 40% of high-ranking scores, was used for participant selection.

4. Anger measurement

Before recording the EEG, the participants completed the State Trait Anger Expression Inventory-2 (STAXI-2) [17]. The Korean version of the STAXI-2 was used to assess the self-reported state, trait, and anger expression. The inventory consists of 57 items rated on a 4-point Likert scale, with response options ranging from 1 ("almost never") to 4 ("almost always"). The STAXI-2 comprises five distinct scales: state anger, trait anger, anger expression-in, anger expression-out, and anger control. The STAXI-2 Trait Anger scale, consisting of ten items, measures participants' general feelings toward statements related to anger experiences. The anger expression-out and anger expression-in scales each consist of eight items that assess participants' typical reactions or behaviors when they experience anger or fury. Anger expression-out refers to externalized ex-

pressions of anger, whereas anger expression-in refers to internalized expressions of anger. Anger expression-out and anger expression-in are not opposing poles on a single continuum but rather orthogonal dimensions that can co-occur [18, 19].

5. Anger elicitation materials

The Articulated Thoughts in Simulated Situations (ATSS) task sequence was used to elicit anger in the participants. This involved presenting a simulation and periodically pausing the flow of the simulation (typically 5-8 times for 30 s) to allow participants to articulate their thoughts in response to the presented scenarios. Prompts for participants to think out loud were given promptly after the completion of each simulation segment, usually through an auditory signal. As the ATSS task focuses on capturing the immediate experience of individuals, it was necessary to ensure that the responses were unrestricted and reflective of the ongoing thought process in the present moment. The participants were instructed to respond in a manner that was not retrospective or conditional (e.g., "If I were in a situation like that, I would probably say/do/think..."). The ATSS task sequence provides situational specificity, allowing for controlled experimental conditions. The response format is unconstrained, enabling participants to express their thoughts freely. The immediate assessment nature of the ATSS facilitates the detection of dynamic cognitive processes and ongoing fluctuations [20].

6. Acupuncture intervention

Acupuncture interventions were applied at GB20 and GB21 according to the guidelines provided by the World Health Organization [21]. The precise localizations for the acupuncture points were as follows: GB20 is located in the anterior region of the neck, below the occipital bone, in the depression between the origins of the sternocleidomastoid and trapezius muscles; and GB21 is located in the posterior region of the neck, at the midpoint of the line connecting the spinous process of the seventh cervical vertebra (C7) with the lateral end of the acromion. The acupuncture treatment was administered by a trained and licensed acupuncturist with more than 3 years of clinical experience. Before the procedure, the insertion sites were sterilized using alcohol. Stainless steel single-use acupuncture needles (0.20 mm × 30 mm; Dongbang Acupuncture, Boryeong, South Korea) were inserted using a tube needling technique. Four acupuncture needles were inserted bilaterally at GB20 and GB21, with a depth of 10 ± 2 mm. The needles were retained for 10 min, and no manipulation was performed during this time [22].

7. EEG data acquisition

A computerized polygraph (QEEG-32FX, Laxtha Inc., Korea) was used to record a total of 32-channel EEGs, consisting of 26 homologous channels and six midline channels. The EEG recordings were performed in a noise-protected and electrically shielded room. The sampling rate was set at 250 Hz. To record the EEG signals, a stretch-Lycra 32-channel EEG cap (ElectroCap, International, Inc., Eaton, OH, USA) with MT100 (Ag/AgCl electrodes) was carefully positioned on each participant's head, following established anatomical landmarks. The electrode placement adhered to the international 10-20 system, encompassing the following channels: FP1, FP2, FPZ, AF3, AFZ, AF4, F7, F3, FZ, F4, F8, FC5, FC1, FC2, FC6, T3, C3, CZ, C4, T4, CP5, CP1, CP2, CP6, T5, P3, PZ, P4, T6, O1, OZ, and O2. Reference electrodes were positioned on A1 and A2. ElectroGel (Eaton, OH, USA) was used as the conducting medium.

During the EEG recording session, the participants were instructed to sit comfortably and minimize body and eye movements. The recording consisted of three segments for each subject: an 8-min resting period, a 9-min period during anger stimulation, and a 16-min period that encompassed the acupuncture intervention and the subsequent post-acupuncture phase. Although the acupuncture needle retention time was 10 min, an additional 6 min were recorded to facilitate data interception and analysis after the removal of the needle. The participants were instructed to keep their eyes closed throughout the recording session.

8. EEG data analysis

EEG data processing was performed using TeleScan (Laxtha Inc., Korea) software. Initially, the raw EEG data were visually inspected to identify any movement artifacts or signal clipping. One participant was excluded from the analysis because of incomplete data due to a mechanical problem. To minimize noise and artifacts, data interception was applied to each EEG segment by excluding 2 min of the head and tail in the first (baseline) and second (anger stimulation) segments. The third segment, which focused on the acupuncture intervention, was

divided into three parts to analyze different stages: the early stage of acupuncture, the end stage of acupuncture, and the period after the removal of acupuncture. The first 4 min following the insertion of the acupuncture needle were designated as the early stage of acupuncture, while the end stage of acupuncture encompassed the 4 min leading up to the removal of the acupuncture needle. The EEG datasets were preprocessed using a 0-50-Hz band-pass digital filter. Frequency analysis was then performed using fast Fourier transform (FFT). During the frequency analysis, the absolute and relative power of specific frequency bands were calculated for each EEG segment. The frequency bands of interest included theta (4-8 Hz), alpha (8-13 Hz), beta (13-30 Hz), and gamma (30-50 Hz).

To compute the FAA, eight pairs of homologous electrodes were selected: FP1 and FP2, AF3 and AF4, F7 and F8, and F3 and F4. Asymmetry was computed by calculating the difference between the alpha values of the left and right electrode sites ([left alpha] – [right alpha]). Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) for Windows, version 22. Frequency analysis was conducted using FFT. Repeated measures ANOVA was conducted to assess the differences in FAA across the five experimental stages. Pairwise comparison judgments were used to further analyze the differences between the stages, with p-values ≤ 0.05 considered statistically significant. Furthermore, the association between the FAA and STAXI-2 scores in each experimental phase was examined using Pearson's correlation analysis.

RESULTS

1. Study flow and characteristics of the participants

Forty-five participants underwent a phone screening process to assess their eligibility. Of these, ten participants were excluded for the following reasons: two participants met the exclusion criteria, two failed in personal contact, and six did not show up for the study. The remaining 35 participants underwent further assessment using the NAS as a screening test. One participant was excluded from the study because their score of 53 did not meet the criterion score of > 75 points. Therefore, 34 participants were enrolled in the experiment. However, data from one participant were excluded from further processing and analysis because of recording errors caused by a mechanical problem (Fig. 1). The baseline characteristics of the participants are summarized in Table 1.

2. Acupuncture effects on frontal alpha asymmetry

Data extraction was conducted for the following five phases: baseline, anger stimulation, early stage of acupuncture, end

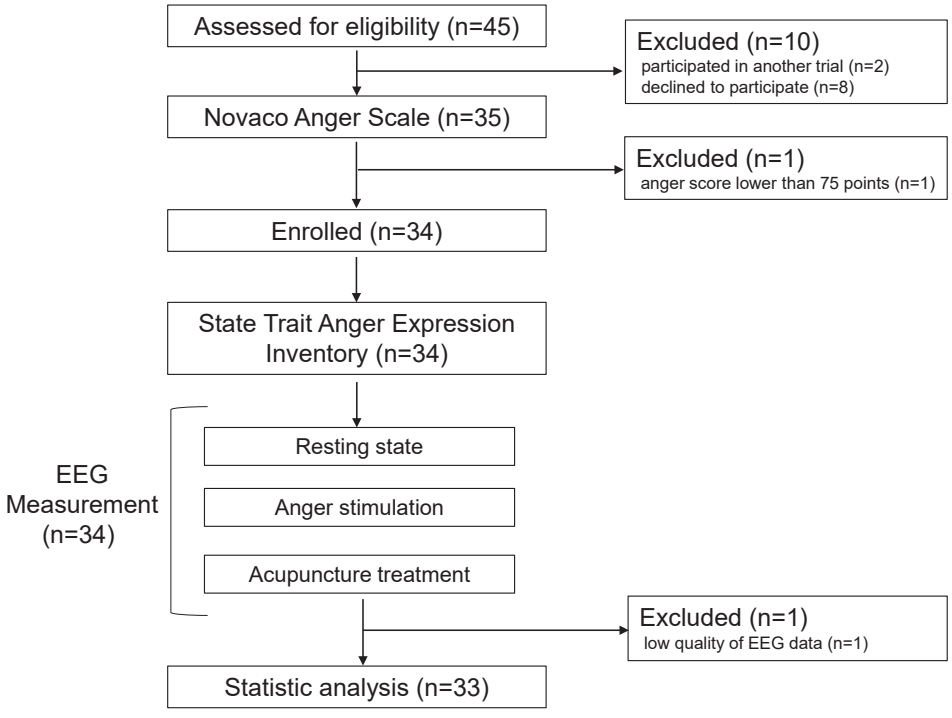

Figure 1. Flow chart.

stage of acupuncture, and after acupuncture removal. The frontal relative alpha powers and asymmetry scores at each stage are presented in Table 2. During the anger stimulation stage, the FAA increased compared to that at baseline, indicating a shift toward greater left hemisphere activation. Following the insertion of the acupuncture needle, the FAA decreased, indicating a reduction in left-sided asymmetry. Interestingly, after the removal of the acupuncture needle, the FAA showed a reversal of asymmetry, moving in the opposite direction (Fig. 2).

These changes in relative FAA were particularly significant in channels FP1 and FP2 located in the prefrontal lobe. In the anger stimulation stage, the relative FAA significantly increased toward the left hemisphere ($p = 0.026$). Upon insertion of the acupuncture needle, the left-sided FAA significantly decreased ($p = 0.027$). At the end stage of acupuncture needle retention, the FAA decreased further and even shifted toward right-sided asymmetry ($p = 0.666$). The tendency of the declining left-sided FAA, opposite to the anger state, remained, although this was not statistically significant. After the removal of the acupuncture needle, the FAA significantly returned to a value between the baseline and the evoked anger stage ($p = 0.046$). Similar trends in the FAA difference were observed in other frontal channels, except for channels F7 and F8, where no significant difference in FAA was observed between the early and end stages of acupuncture.

3. Association between STAXI-2 scores and FAA

The association between STAXI-2 scores and FAA is presented in Table 3. Significant associations were observed between trait anger and left-sided FAA during the anger stimulation stage (Pearson's correlation coefficient = 0.366, $p = 0.036$) and the early stage of acupuncture (Pearson's correlation coefficient = 0.352, $p = 0.045$). Furthermore, there was a significant relationship between anger expression-out and greater left FAA during the anger stimulation stage (Pearson's correlation coefficient = 0.363, $p = 0.038$). Among the different stages, the anger stimulation stage exhibited a stronger asymmetry between left-sided relative alpha power and right-sided power in subjects with higher levels of trait anger and a tendency to express anger

Table 1. Demographic and characteristics of participants

Variables		Total (n = 33)
Age, y		33.24 (12.93)
Sex, male/female		12/21
NAS total score		87.47 (9.48)
STAXI-2	State anger	15.82 (7.05)
	Trait anger	25.79 (4.97)
	Anger control	18.79 (4.24)
	Anger in	19.42 (3.49)
	Anger out	20.67 (3.65)

NAS, Novaco Anger Scale; STAXI-2, State-Trait Anger Expression Inventory-2. Data are presented as mean (standard deviation).

Table 2. Pre-frontal and frontal relative alpha power and asymmetry scores at each stage (n = 33)

Electrode	Relative alpha (8-13 Hz) power, %				
	Baseline	Anger stimulation	Early stage of acupuncture	End stage of acupuncture	After removal of acupuncture
FP1	54.38 (0.15)	49.34 (0.16)	49.04 (0.14)	41.39 (0.15)	44.74 (0.16)
FP2	53.76 (0.15)	46.88 (0.16)	48.85 (0.15)	41.51 (0.15)	43.07 (0.16)
FP1-FP2	0.24 (0.06)	2.33 (0.08)	0.16 (0.07)	−0.18 (0.05)	1.46 (0.06)
F7	51.64 (0.16)	49.19 (0.17)	46.04 (0.18)	40.58 (0.17)	42.42 (0.19)
F8	52.06 (0.16)	48.04 (0.18)	48.72 (0.16)	41.86 (0.16)	42.71 (0.18)
F7-F8	−0.42 (0.06)	1.15 (0.06)	−1.08 (0.07)	−1.08 (0.07)	1.43 (0.07)
F3	55.21 (0.14)	51.58 (0.16)	53.01 (0.16)	46.17 (0.17)	48.88 (0.17)
F4	56.05 (0.16)	51.53 (0.17)	53.42 (0.17)	47.23 (0.17)	48.77 (0.17)
F3-F4	−0.84 (0.06)	0.05 (0.06)	−0.41 (0.05)	−1.06 (0.05)	0.11 (0.05)
AF3	56.91 (0.16)	52.17 (0.17)	53.24 (0.16)	45.43 (0.17)	47.82 (0.17)
AF4	54.68 (0.16)	50.95 (0.16)	53.00 (0.17)	46.20 (0.16)	46.89 (0.17)
AF3-AF4	0.07 (0.06)	1.22 (0.06)	0.24 (0.06)	−0.77 (0.05)	0.92 (0.05)

Data are presented as mean (standard deviation).

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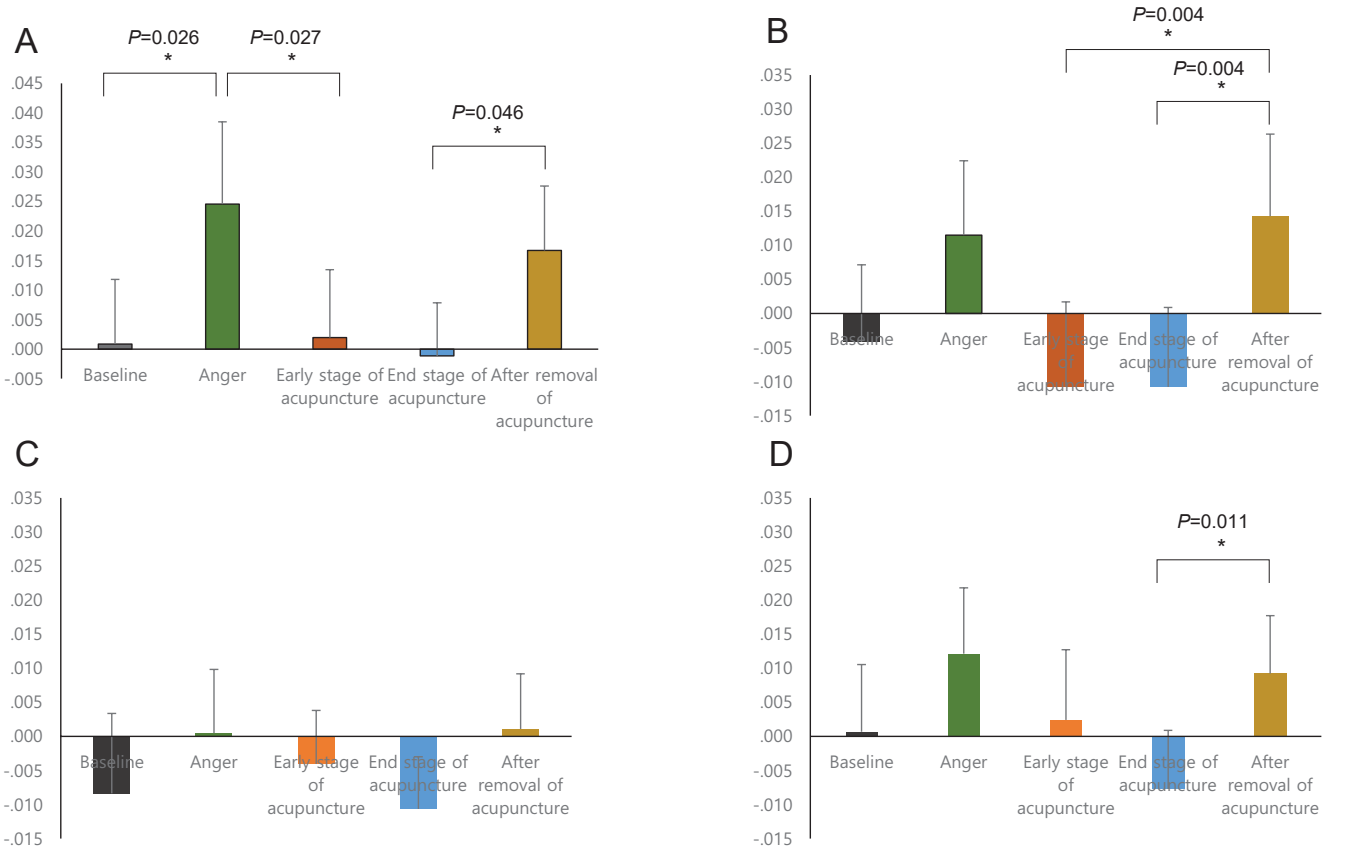

Figure 2. Relative alpha power asymmetry. (A) FP1-FP2; (B) F7-F8; (C) F3–F4; (D) AF3-AF4. *Asymmetry was derived by difference value between left and right sites ([left alpha] – [right alpha]).

Table 3. Relationship between STAXI-2 score and FAA (n = 33)

		Baseline	Anger stimulation	Early stage of acupuncture	End stage of acupuncture	After removal of acupuncture
State anger	PC	–0.041	0.084	0.050	0.192	–0.031
	p-value	0.822	0.640	0.784	0.285	0.866
Trait anger	PC	0.195	0.366*	0.352*	0.293	0.176
	p-value	0.277	0.036	0.045	0.098	0.327
Anger control	PC	–0.128	–0.269	–0.093	0.168	–0.137
	p-value	0.479	0.131	0.608	0.351	0.447
Anger-out	PC	0.193	0.363*	0.269	0.193	0.083
	p-value	0.281	0.038	0.130	0.283	0.644
Anger-in	PC	0.068	0.073	0.175	0.160	–0.064
	p-value	0.708	0.688	0.331	0.374	0.725

*PC, Pearson's correlation coefficient.

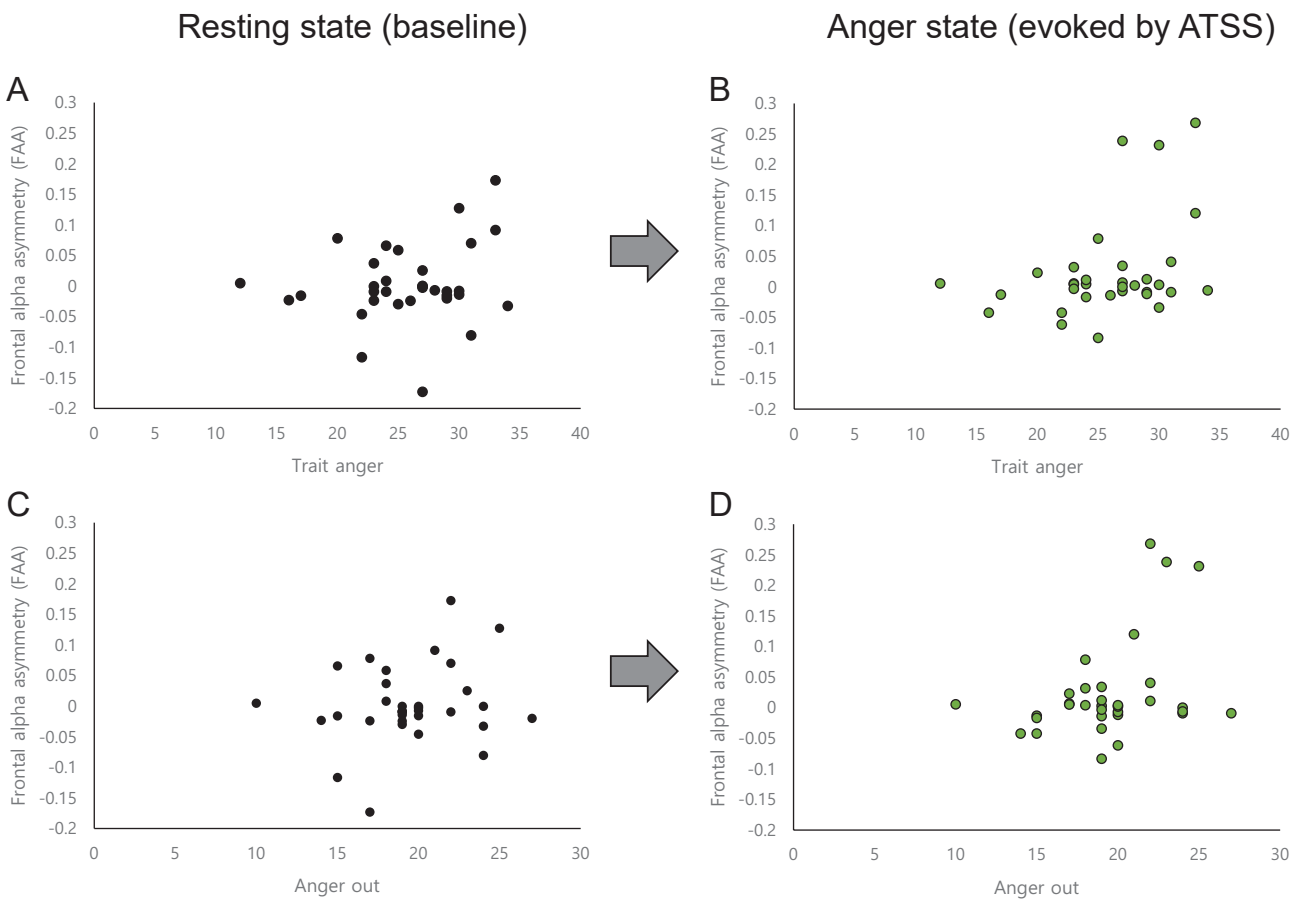

Figure 3. Association between frontal alpha asymmetry (FAA) and STAXI-2 subscales. (A) FAA and trait anger in resting state; (B) FAA and trait anger in anger state; (C) FAA and anger out in resting state; (D) FAA and anger out in anger state.

rather than suppress it when anger is evoked (Fig. 3).

DISCUSSION

This study presents preliminary findings indicating that acupuncture treatment at GB20 and GB21 effectively alleviates the increased asymmetry of the alpha power in the frontal lobe, particularly in the left hemisphere, which is associated with anger. Additionally, no adverse events related to the acupuncture intervention were reported. Pharmacological interventions are commonly used as first-line treatments for anger control dysfunctions, such as intermittent explosive disorder, bipolar disorder, and impulse control disorder. However, these medications, including opioid antagonists, glutamatergic agents, and mood stabilizers, may be associated with significant adverse effects such as increased anxiety and gastrointestinal problems [23]. As a result, there is a growing demand for alternative treatments with fewer side effects. The results of this preliminary study suggests that acupuncture could be considered as a complementary and alternative therapy for anger management.

In this pilot study, we sought to assess the feasibility of using acupuncture to alleviate anger by modulating EEG. The study followed a sequential procedure, starting with the induction of emotional stimulation, followed by acupuncture treatment and observation of immediate effects on EEG in real time. This approach allowed us to explore the safety of acupuncture and its immediate impact within a specific time frame. We also conducted the NAS test during the screening period, which helped to exclude participants with low baseline anger who were considered unlikely to respond adequately to the anger induction protocol. By implementing this step, we were able to effectively provoke anger and measure FAA. Additionally, we analyzed the correlation between trait anger and anger expression-out scores from the STAXI-2 questionnaire and FAA. Our findings revealed a positive association, indicating that higher levels of trait anger and anger expression-out were linked to greater

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asymmetry in the frontal lobe EEG. This correlation aligns with the results of previous studies that demonstrated a proportional relationship between these factors when anger was triggered by visual stimuli [6, 24]. We selected the acupoints GB20 and GB21 based on the meridian theory of Korean medicine, specifically the gallbladder meridian, which passes through the prefrontal and frontal lobes. Our study showed significant differences in these brain regions, providing preliminary evidence of the efficacy of these acupoints in relieving anger. However, because of the limited number of studies on this topic, these findings should be interpreted with caution until further scientific evidence is accumulated. Future trials are needed to investigate the underlying mechanisms based on meridian theory and EEG analysis.

This study has several limitations that should be considered. First, the absence of a control group limits our ability to fully establish the specific effects of acupuncture on FAA. The inclusion of a control group that received either a placebo or no intervention would have strengthened the interpretation of the results and would have provided a clearer understanding of the impact of acupuncture on FAA. Second, it is important to acknowledge that natural variations in FAA over time could have influenced the results. Third, as the acupuncture intervention in this study was administered only once, and the observation period after the removal of acupuncture was relatively short, the observed rebound effect may be attributed to the immediate post-treatment response rather than the long-term effects of acupuncture. It is plausible that a longer treatment period and extended observation time after treatment removal would provide a more comprehensive understanding of the sustained effects of acupuncture on FAA. To address these limitations, future studies should include a control group and employ multiple acupuncture treatments to assess the cumulative effects over time. Additionally, longer observation periods after treatment removal would allow for a more accurate evaluation of the sustained effects of acupuncture.

CONCLUSION

Our findings serve as preliminary evidence supporting the feasibility of acupuncture treatment at GB20 and GB21 as a potential intervention for individuals exhibiting FAA. The observed safety profile and immediate effects suggest that acupuncture is a viable treatment option for individuals struggling with anger control difficulties. However, further research is warranted to establish its efficacy and explore its long-term effects in a larger population.

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AUTHORS' CONTRIBUTIONS

SA Kim, Y Choi, and SH Cho conceived and designed the study. SA Kim and Y Choi contributed to data acquisition, analysis, and interpretation, while SH Cho provided supervision throughout the research. SA Kim drafted the original manuscript, which was critically revised by the other authors. All authors have read, edited, and given their approval for the final manuscript.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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