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ORIGINAL RESEARCH

Correlation between precontemplation and alpha activity in gambling disorder

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Jaewon Lee[1],*
Sam-Wook Choi[2],*
Kyoung Min Kim[3]
Young Sik Lee[4]
Jun Won Kim[5]

[1]Department of Psychiatry, Easybrain Center, Seoul, Republic of Korea; [2]Department of Psychiatry, True Mind Mental Health Clinic, Seoul, Republic of Korea; [3]Department of Psychiatry, Dankook University Hospital, Cheonan, Republic of Korea; [4]Department of Psychiatry, Chung-Ang University, College of Medicine, Seoul, Republic of Korea; [5]Department of Psychiatry, Catholic University of Daegu School of Medicine, Daegu, Republic of Korea

*These authors contributed equally to this work

Purpose: Gambling disorder is a psychiatric condition characterized by persistent and recurrent maladaptive gambling. In the present study, we evaluated the characteristics of resting-state electroencephalogram (EEG) recordings in patients with gambling disorder. In addition, we explored the association between the EEG characteristics of the patients and the stages of change in a transtheoretical model.

Methods: All participants were men who visited a gambling disorder clinic in Seoul, Korea. At the assessment, questionnaires, including the Readiness to Change Questionnaire (RCQ), were administered and resting-state EEGs were carried out. Participants were grouped based on Ward's method for cluster analysis. Independent sample *t*-tests were used to evaluate group differences. To assess the relationship between the clinical data and the EEG recordings, we used Pearson's partial correlation analysis.

Results: Overall, 63 male participants were enrolled. Cluster analysis of the alpha activity revealed two clusters. No significant differences were observed in the demographic or clinical data between the two groups except for the Beck Depression Inventory (BDI). We found that the precontemplation score of the RCQ was positively correlated with the z-score of the relative alpha power in almost all cortical regions.

Conclusion: This study suggests that EEG parameters, particularly alpha activity, could inform us about the subtypes or stages of change in gambling disorder. Alpha power is the predominant EEG rhythm in a relaxed, alert person; thus, alpha power serves as an index of relaxation. We expect that the level of alpha activity could be utilized as an additional parameter to help clinicians assess and treat patients with gambling disorder.

Keywords: quantitative electroencephalography, gambling disorder, stages-of-change model, alpha activity

Introduction

Gambling disorder is a psychiatric condition characterized by persistent and recurrent maladaptive gambling that causes financial problems and significant disturbances in personal, social, or occupational functioning. The prevalence rate of problem gambling or gambling disorder in the general population is 0.12~5.8%,[1] and the lifetime prevalence rates for gambling disorder have been estimated to be approximately 0.5%.[2] Historically, as the diagnostic system of the DSM (Diagnostic and Statistical Manual of Mental Disorders) changed, the diagnostic term and category for gambling disorder also changed. In the DSM-IV, pathological gambling was the official diagnostic term, which was categorized as an impulse-control disorder because of the preoccupation and compulsion that the patients have with gambling. In 2013, the DSM was revised to the DSM-5, and gambling

Correspondence: Jun Won Kim
Department of Psychiatry, Catholic University of Daegu School of Medicine, 3056-6 Daemyeong-4 dong, Nam-gu, Daegu 705-718, Republic of Korea
Tel +82 53 650 4332
Fax +82 53 623 1694
Email f_affection@naver.com

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disorder became the official diagnostic term, which was categorized as a substance and addictive disorder.[3] The diagnostic criteria of gambling disorder, which include tolerance and withdrawal, resemble those of substance and addictive disorders. In addition, because substance use frequently accompanies gambling disorder, we infer similarities between the two disorders in the clinical context. In fact, gambling disorder and other addictive disorders are similar in cause, biological basis, course, clinical characteristics and treatment, and these similarities seem to have led to the change in diagnostic category.[4]

Abnormalities in electroencephalogram (EEG) activity in gambling disorder have been reported in many articles. In an early EEG study comparing eight patients with pathologic gambling (the official diagnostic term for gambling disorder in the DSM-IV) and eight healthy controls, the pathologic gamblers did not show a significant shift in EEG activity between hemispheres. If a shift occurred, more time was required. Interhemispheric EEG coherence is one indicator used to quantify the cortical connectivity between two spatially distributed areas of the brain.[5] In another study, the differences observed in interhemispheric coherence in the frontotemporal areas between pathologic gamblers and controls were proposed to possibly result from varying susceptibility of the frontolimbic circuitry function to stress.[6] Based on this speculation, the authors described an inability of pathological gamblers to shift brain activation and asserted that this characteristic of pathological gamblers may be related to perseveration and persistence in gambling.[7] In a study by Regard et al, the percentage of people who had dysfunctional EEG recordings was higher among pathological gamblers (65%) than that among normal healthy controls (26%). In eleven pathological gamblers with dysfunctional EEG recordings, nine had abnormalities in the temporal area, and two had focal slowing in the posterior region.[8] Shemchuk et al estimated brain functional states using EEG data and reported (1) abnormalities in the amplitude and frequency characteristics of the alpha rhythm and (2) disturbances in the mechanisms of synchronized slow-wave generation associated with the alpha-rhythm abnormalities.[9] Alpha power is the predominant EEG rhythm in a relaxed, alert person; thus, alpha power serves as an index of relaxation.[10] The amplitude of alpha oscillations reflects whether the brain is biased toward processing stimuli from the external world or toward processing internal representations.[11] In other words, alpha power is implicated in inhibitory functions and is involved in cognitive processes associated with attention and memory.[12]

Frontal lobe abnormalities in patients with gambling disorder have also been consistently reported. These abnormalities were interesting particularly in the prefrontal cortex (PFC), which plays an important role in human decision making.[13] One electrophysiological study using EEG provided evidence of PFC involvement in motivation and emotion. The left PFC was correlated with approach-related and reward-related motivation and emotion, while the right PFC was correlated with withdrawal-related motivation and emotion.[14,15] These approach- and withdrawal-related emotions were mutually inhibited and maintained in equilibrium and are called “reward and punishment contingencies”.[16] When this balance was disrupted, reward bias developed. Reward bias, which refers to the disturbances in decision making frequently observed in gambling disorder and substance use disorder, was due to cortical frontal asymmetry, or in other words, a left lateralization effect.[17] Cortical lateralization was measured by EEG using alpha band analysis.[18]

Addictive behavior is not changed immediately but through a series of stages. One theory regarding these stages is the stage-of-change model.[19] According to the model, the change consists of continuous stages, namely, precontemplation, contemplation, action and maintenance. At each stage, readiness to change has prognostic value in predicting the results of treatment. The stage-of-change model could also be applied to gambling disorder, using simple questions about recent gambling behavior for the staging,[20] including questions concerning whether the patient quit or cut back his or her gambling behavior significantly within the last 6 months (action), whether he/she is seriously thinking of quitting or cutting down his/her gambling behavior in the next 30 days (preparation), whether he/she is seriously thinking of quitting or cutting down his/her gambling behavior in the next 6 months (contemplation) and whether he/she is not thinking of quitting or cutting down this/her gambling behavior (precontemplation).[21] Likewise, in gambling disorder, the stage-of-change model can help predict decreases in addictive behavior and must be assessed for treatment formulation. According to Petry, in a sample of pathological gamblers, high scores in precontemplation were related to less severe gambling.[20] In agreement with this result, precontemplation had a negative relation with gambling-related problems at the beginning of treatment.[22] In addition, the action and maintenance stages were related to high treatment response, and precontemplation was associated with low levels of therapeutic change.[20]

In other words, the stage-of-change model could reflect the severity of symptoms upon assessment in gambling disorder, and this model can also be used as an important index for predicting treatment response, prognosis and so on. Therefore, we explored the neurophysiological markers to assess precontemplation in the stage-of-change model. As we mentioned before, EEG alpha activity has been reported to be related to the reward-punishment system in addictive disorders and reveals a fundamental process in decision making. Therefore, we hypothesized that alpha activity is closely associated with precontemplation in gambling disorder.

Materials and methods

Participants

Individuals who visited the gambling disorder clinic at Gangnam Eulji Hospital were considered for inclusion in the study. The inclusion criteria were diagnosis of gambling disorder according to the DSM-5 criteria, male, and age between 18 and 65 years old. Participants were excluded if any of the following criteria were met: a diagnosis of substance use disorder other than to nicotine and caffeine based on the DSM-5; the use of psychotropic medications over the last year; or the presence of a physical, mental or neurological disorder. Based on the inclusion and exclusion criteria, 63 male participants (aged: 38.27±11.51 years) were enrolled in this study. None of the participants were taking any medications, and all had completed at least 12 years of education (14.76±1.88 years). This study was approved by the Institutional Review Board (IRB) of the Eulji medical center (Seoul, South Korea) and was performed in accordance with the Declaration of Helsinki (World Medical Association: Ethical Principles for Medical Research Involving Human Subjects, 1964). All study participants were provided written informed consent prior to their inclusion in the study.

Readiness to change questionnaire (RCQ)

The Readiness to Change Questionnaire (RCQ) is a 12-item questionnaire based on a transtheoretical model and is designed to measure the stage of change in regard to alcohol use in nontreatment-seeking drinkers.[23] All responses are rated on a 5-point Likert scale from strongly disagree (1) to strongly agree (5). We modified all the questions to address gambling rather than alcohol. Sample items include “I enjoy my gambling, but sometimes, I gamble too much” and “I am actually changing my gambling habits right now”. The RCQ provides scores for precontemplation, contemplation and action subscales, with the stage of change designated by the subscale on which the respondent scores highest. Evidence of the validity of the RCQ has been reported, along with the following Cronbach alpha coefficients: precontemplation=0.940, contemplation=0.938, and action=0.967.[24]

EEG recording and pre-processing

EEG recordings were performed using a SynAmps2 direct-current (DC) amplifier and a 10–20 layout 64-channel Quick-Cap electrode-placement system (Neuroscan Inc., NC, USA). The EEG data were digitally recorded from 19 gold cup electrodes placed according to the international 10–20 system. The impedances were maintained below 5 kΩ, and the sampling rate was 1,000 Hz. We used the linked mastoid reference and two additional bipolar electrodes to measure horizontal and vertical eye movements. During the recording, each participant laid in a semi-darkened, electrically shielded, sound-attenuated room. A resting EEG was recorded after three minutes with the participant’s eyes closed. The participants were instructed to relax and not to think of anything.

We used MATLAB 7.0.1 (Math Works, Natick, MA, USA) and the EEGLAB toolbox[25] to pre-process and analyze the EEG recordings. First, the EEG data were downsampled to 250 Hz. Next, the EEG data were detrended and mean-subtracted to remove the DC component. A 1-Hz high-pass filter and a 60-Hz notch filter were applied to remove eye and electrical noise. Next, independent component analysis (ICA) was performed to remove the well-defined sources of artifacts. ICA has been demonstrated to reliably isolate artifacts caused by eye and muscle movements and heart noise.[26] Finally, a clinical psychiatrist who was experienced in analyzing EEG data visually inspected the corrected EEGs. For the analysis, we excluded EEG recordings that were likely caused by eye and muscle movements and heart noise and selected more than two minutes of artifact-free EEG readings.

EEG analysis

Four frequency bands were defined for further analysis: delta (1–4 Hz), theta (4–8 Hz), alpha (8–12 Hz), and beta (12–30 Hz). We investigated the power spectra of the EEG data from each subject using the short-time Fourier transform “spectrogram.m” function from the Signal Processing Toolbox in MATLAB. Time windows of 1,000 ms with an 800-ms overlap and the Hamming window were used for the spectral analysis. Outliers that were far from the spectral value distribution of each frequency band at the 0.05 significance level were removed. The data from the participants were converted to z-scores based on the means and standard deviations of the NeuroGuide normative database.[27] The z-scores provided comparable estimates of excesses or deficiencies of power for each frequency band at each electrode for each individual with gambling disorder to those in the normative database.

Statistical analysis

The MATLAB 7.0.1 Statistical Toolbox was used for the statistical analyses. All of the values are expressed as the mean and the standard deviation (SD). First, the participants were grouped according to Ward's method of cluster analysis using the squared Euclidian distance as the measure of dissimilarity. The variables used in the cluster analysis were the absolute power and relative power of 19 electrodes in each of the four frequency bands. Discriminant function analysis was performed on the subject clusters identified in the cluster analysis to determine the level of correct classification of the participants based on the EEG data. In the next stage, independent sample t-tests were used to test for group differences in the demographic, clinical, and EEG data. To assess the relationship between the clinical data and EEG recordings, we used a Pearson partial correlation analysis that controlled for age, education, the Beck Depression Inventory (BDI), and the Beck Anxiety Inventory (BAI). Statistical significance was defined as $p<0.05$. To control for false positives due to multiple comparisons, we used the false discovery rate (FDR) correction in which the p-values were multiplied by the number of comparisons.[28]

Results

Demographic and clinical data

The total sample comprised 63 male individuals with gambling disorder (mean age [SD]=38.27 [11.51] years). The cluster analysis derived two clusters from the QEEG parameters: gambling disorder with increased alpha power (N=13) and gambling disorder with normal alpha power (N=50). There were no significant differences in age or the level of education between the two groups. Similarly, no significant differences were observed in the BAI, BIS, LSNS, WURS, CPGI, GSAS, or RCQ between the two groups. However, the BDI score of group 1 was significantly higher than that of group 2. The demographic and clinical data are summarized in Table 1.

Comparison between the two groups: QEEG activity

Figure 1 shows the scalp topographies of the total sample and of the two groups divided by the cluster analysis in terms of the z-scores of the absolute power in each frequency band. Group 1 had significantly higher alpha power than group 2 at all 19 electrodes (Fp1, Fp2, F3, F4, C3, C4, P3, P4, O1, O2, F7, F8, T3, T4, T5, T6, Fz, Cz and Pz). All significant

Table 1 Comparisons of demographic and clinical symptom scores between two groups

	Group 1 (N=13)	Group 2 (N=50)	t	*p*
Age (year)	40.69±12.17	36.21±10.67	1.56	0.124
Education (year)	14.28±1.98	15.18±1.71	−1.94	0.058
BDI	18.79±9.74	13.71±9.24	2.12	0.038*
BAI	14.31±11.25	10.21±8.30	1.66	0.102
BIS	57.79±8.60	54.47±7.46	1.64	0.105
LSNS	25.59±5.82	24.38±4.73	0.91	0.368
WURS	31.31±19.58	27.03±13.20	1.03	0.307
CPGI	19.9±6.03	17.29±6.46	1.58	0.120
GSAS	23.41±13.79	22.12±10.74	0.42	0.677
RTCQ				
Pre-contemplation	−3.34±3.15	−3.88±3.94	0.59	0.560
Contemplation	5.62±2.24	5.55±2.09	0.14	0.891
Action	3.90±3.07	2.88±3.73	1.17	0.247

Note: *$P\leq0.05$.
Abbreviations: BDI, Beck Depression Inventory; BAI, Beck Anxiety Inventory; BIS, The Korean version of Barratt Impulsiveness Scale; LSNS, Lubben Social Network Scale; WURS, Wender-Utah Rating Scale; CPGI, Canadian Problem Gambling Index; GSAS, Gambling Symptom Assessment Scale; RTCQ, Readiness To Change Questionnaire.

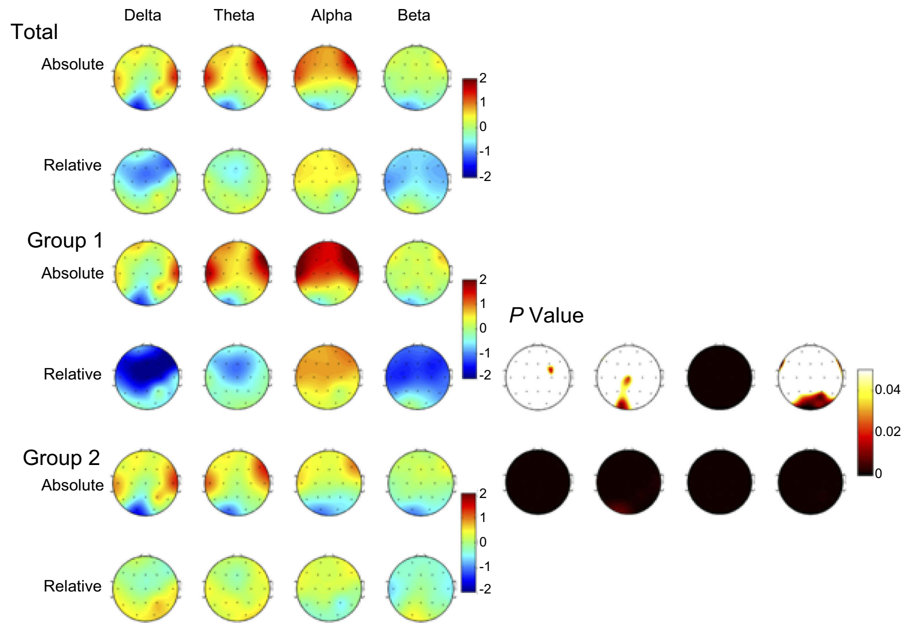

Figure 1 Topographical maps of the absolute and relative powers in patients with gambling addiction. Scales show the uV^2 for absolute power and the % for relative power. Red represents higher values, and blue represents lower values. The left topography denotes the topographical distribution of the z-score of electroencephalogram power. The right topography denotes the topographical distribution of *p*-values between group 1 and group 2 (Independent *t*-test).

differences were FDR-corrected (corrected $p<0.05$). Regarding the theta power, group 1 had significantly higher values than group 2 at 2 of the electrodes (Cz and O1) (corrected $p<0.05$). Regarding the beta power, group 1 had significantly higher values than group 2 at 3 of the electrodes (P4, O1 and O2) (corrected $p<0.05$).

Correlation analysis

Pearson's partial correlation analyses were performed for the clinical data and EEG recordings. We found that the precontemplation score of the RCQ was positively correlated with the z-scores of the relative alpha power. Significant findings were revealed in all cortical regions except for P4 ($p=0.05$). The scatter plots and topographical features of Pearson's partial correlation analysis between the precontemplation score of the RCQ and the average z-score of the relative alpha power ($r=0.402$, $p=0.002$) are presented in Figure 2. No significant relationship was found between other clinical data and the average z-score of the other EEG frequencies.

Discussion

In this study, we assessed and collected EEG recordings from 63 males who visited a gambling disorder clinic in Seoul, Korea. According to the alpha power, which is one

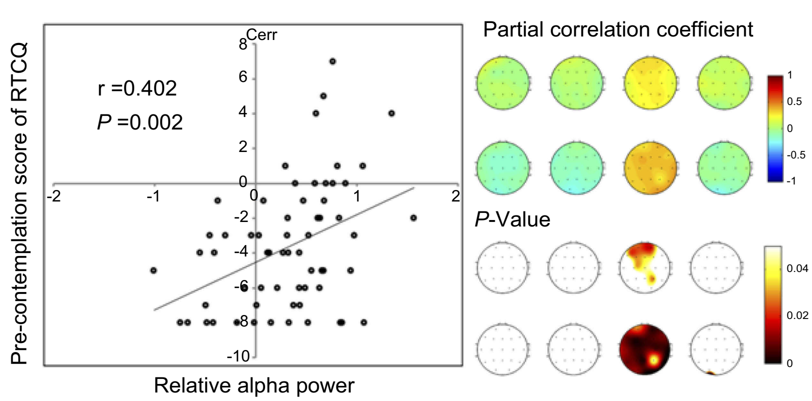

Figure 2 Scatter plots of the Pearson's partial correlation analysis controlled for age, education, BDI and BAI between z-score of relative alpha power and pre-contemplation score of RTCQ.

Abbreviations: BDI, Beck Depression Inventory; BAI, Beck Anxiety Inventory; RTCQ, Readiness To Change Questionnaire.

of the QEEG parameters, there was a cluster analysis of two clusters (group 1 and group 2). Group 1 exhibited higher alpha power than group 2 in all electrodes. In addition, the correlation analysis of the clinical data and EEG recording showed a positive correlation between precontemplation and alpha power.

There have been many trials to determine the subtypes of gambling disorder, and in fact, clinicians have admitted that patients with gambling disorder are heterogeneous.[29] Gambling disorder subtypes are not classified in the DSM, but many previous studies classified subtypes of gambling disorder into the "sensation-seeking type" and the "maladaptive type".[30] The sensation-seeking type involves the personality trait of novelty-seeking. Individuals with this subtype tend to be more impulsive and to have more intense cravings compared to individuals with other subtypes. Men are more common in this type, onset occurs earlier, and there is a greater likelihood of a family history of the disorder. In the early phase, individuals with this subtype exhibit multiple addictive tendencies and are suspected to have abnormalities in the dopaminergic system of the brain.[31,32] The maladaptive type consists of individuals who are introverted, timid, depressive and have greater difficulty with social adjustment. Women are more common in this type, onset occurs later than in the sensation-seeking type, and individuals with this subtype are more interested in relations than in gambling itself.[33] The types of preferred gambling also facilitate the classification of gambling disorder. Strategic gambling, in which one's technique and skill could affect the result of the game, includes horse racing, cycle racing, stocks and poker. Nonstrategic gambling, which involves games of chance, includes the lottery and slot machines. In a previous study, patients who developed gambling disorder at an early age were less likely to belong to the maladaptive type, prefer strategic and internet gambling, and exhibit delayed time at the first treatment. On the other hand, patients who developed the disorder at older ages were found to be more prone to the maladaptive type and to engage in nonstrategic gambling.[34,35]

In the present study, patients were classified into two groups by cluster analysis. Group 1 (N=13) exhibited greater alpha power than Group 2 (N=50), which exhibited normal alpha power. Alpha power, unlike the other EEG parameters, could categorize the pathological gamblers precisely. As far as is known, alpha power is the predominant EEG rhythm in a relaxed, alert person; indeed, alpha power serves as an index of relaxation.[10] However, there is an increase in alpha activity in the front of the head in an abnormal or diseased state. When the amplitude of alpha oscillations increases, the oscillations mostly reflect ADHD or a depressed state.[36] In addition, the amplitude of alpha oscillations reflects whether the brain is biased toward processing stimuli from the external world or toward processing internal representations.[11] Higher alpha power represents brain states concentrated toward the internal world, and in this state, it is difficult for the brain to perceive external stimuli. In other words, alpha power is implicated in inhibitory functions and is involved in cognitive processes associated with attention and memory.[12] In a previous study analyzing the same study participants as this study, problem gamblers with high impulsivity showed decreased alpha power in frontocentral regions.[37]

In the present study, group 1 had significantly higher BDI scores than group 2. Therefore, we can infer that group 1 aligned with the maladaptive subtype. The maladaptive type is a subtype that is associated with high levels of depression, anxiety and stress. Individuals with this subtype are introverted, have difficulty in social relationships, and show low social adaptation ability.[38] These individuals engage in gambling to avoid negative emotions and use gambling as a means of avoiding states of arousal, in contrast to the sensation-seeking type. This finding is in agreement with the findings of previous studies that higher alpha power represents brain states concentrated toward the internal world or a depressed state.[11] On the other hand, group 2, which exhibited lower alpha power than group 1, aligned with the sensation-seeking type, which is characterized by increased external world orientation and impulsivity; however, further studies are needed to confirm this idea.

In the case of the second main outcome, we found that the precontemplation score of the RCQ was positively correlated with the z-score of the relative alpha power in all cortical regions except for P4 (r=0.402, p=0.002). In the transtheoretical model, precontemplation is characterized by an absence of the intention to change and a lack of awareness of problems.[39] High scores on precontemplation were found to be associated with low levels of gambling severity, low levels of therapeutic change[20] and premature termination from therapy.[40] From this point of view, the fact that alpha activity, which reflects inhibitory functions, had a positive relationship with the precontemplation stage is explainable. In clinical settings, the stages-of-change model could be used to assess the current severity of problem gambling and to predict the treatment course and results, yet its assessment depends only on a self-report scale. The study suggested that EEG parameters could be utilized adjunctively and could help clinicians in assessing and treating problem gambling.

In a number of previous studies of alpha activity and addiction, right and left difference in alpha activity in the PFC affected the reward-punishment system, which led to malfunctions in decision making, increasing the possibility of addiction.[17] Cortical imbalance in the alpha band, eg, left PFC predominance (alpha reduction), was estimated in a group with higher IAT (internet addiction inventory) and BAS (behavioral activation system) scores, and the authors hypothesized that left lateralization resulted in reward bias, leading to behavioral addiction.[41] However, in the present study, changes in alpha activity were measured in all cortical regions. Right and left differences or predominance in specific regions were not found. Henceforward, by additional analysis of the regional differences in alpha activity, assessments of the correlation between symptom severity and alpha power will be needed.

There were several limitations to this study. First, the sample only contained male gambling disorder patients and no healthy controls, so any generalization of the results may be limited. In addition, though cluster analysis was done, the number of participants, ie, 13 (group 1) and 50 group 2), was not large enough to determine the clinical significance. Whether we can classify gambling disorder by using the differences in alpha activity or utilize the alpha wave as a novel tool to designate the subtypes of gambling disorder are still questions that need to be answered. If we want to answer these questions, we need further studies using EEG and additional analyses of traits or personality. Second, the age range of the participants was broad, ranging from 20 to 65 years. The power of EEG frequency bands is known to be variable according to age, although the changes in EEG power during adulthood are less remarkable than those during childhood.[42] Additionally, the characteristics of gambling can show age-dependent features.[43] A future study with an age-matching design or a narrow age span is warranted to overcome this limitation. Third, the comorbidities of patients in the sample were restricted. Although it is known that gambling disorder is associated with comorbidities, including depression, anxiety disorders, obsessive-compulsive disorder, and ADHD, this study measured only depressive symptoms. Finally, the 19 electrodes that were used in this study were not enough to evaluate the topographical function of the brain. Future studies with more electrodes are warranted to perform more thorough investigations of topographical brain function.

Conclusion

In treating gambling disorder, assessment of the disease is very important for gathering and interpreting the information necessary to plan the treatment and to observe the treatment course.[44] In the assessment stage, clinicians determine the severity of the addiction, motivation to change, insight, and social support system of the patient and then utilize this information. Clinicians assess the subtypes of gambling disorder, symptom severity, comorbidities and in what stage a patient belongs in the stage-of-change model. However, currently, classification of subtypes or the stage of change depends exclusively on a self-report scale or on the assessment of clinicians. This study suggests that EEG parameters, including alpha waves, could be used to determine a patient's subtype or stage of change, particularly the precontemplation stage. Additional studies will be needed to validate the alpha wave as a reliable neurophysiological marker.

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Disclosure

The authors report no conflicts of interest in this work.

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