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Neurophysiological correlates of resilience in patients with Internet gaming disorder: A resting-state EEG study

인터넷 게임 장애에서 회복탄력성 연관 신경생리학적 지표 규명: 휴지기 뇌파 연구

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Abstract

Neurophysiological correlates of resilience in patients with Internet gaming disorder: A resting-state EEG study

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Internet gaming disorder (IGD) has been defined as persistent and excessive use of the Internet, to participate in games, which results in psychological impairment or distress. Resilience, an important protective factor against IGD, is the ability to recover from negative emotional experiences and constitutes a flexible adaptation to stress. Despite the importance of resilience in predicting IGD, little is known about the relationships between resilience and the neurophysiological features of IGD patients.

Thus, the present study investigated these relationships in 71 males using resting-state electroencephalography (EEG), by comparing IGD patients (n = 35) to healthy controls (HC; n = 36). To identify the EEG features related to resilience, the IGD patients were divided into two groups based on the 50th percentile score on the Connor–Davidson Resilience Scale (CD–RISC): IGD with low resilience (LowRe–IGD; n = 16) and IGD with high resilience (HighRe–IGD; n = 19). First, generalized estimating equations (GEEs) were used to analyze differences in EEG absolute power in terms of resilience (LowRe–IGD, HighRe–IGD, HC), brain region (frontal, central, posterior), and hemisphere (left, right) for each fast frequency band (alpha, beta, and gamma). Second, EEG coherence analyses were conducted to compare functional brain connectivity among the LowRe–IGD, HighRe–IGD, and HC groups. Finally, moderated mediation analyses were performed to examine the conditional indirect effects of resilience on the relationships between IGD and specific EEG features through clinical symptoms (depressive symptoms and stress level).

IGD patients with low resilience had lower alpha absolute power than HC, and higher alpha coherence in the right hemisphere than the HighRe–IGD and HC groups. Among all subjects, only alpha coherence in the right hemisphere had a negative correlation with resilience and positive correlations with depressive symptoms and stress level. In particular, indirect effects of IGD on alpha coherence in the right hemisphere through depressive symptoms and stress level were moderated by resilience. i.e., IGD with lower resilience had more severe depressive symptoms and higher stress level, which it was related with increased alpha coherence in the right hemisphere.

These novel neurophysiological findings regarding the mechanisms underlying resilience may provide a new perspective for understanding IGD and help to establish effective preventive measures against, and treatments for, this disorder.

Keyword: Internet gaming disorder, resilience, resting−state electroencephalography (EEG), coherence

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Introduction

The Internet has quickly become essential to our daily lives because it constitutes an endless source of information and entertainment. In particular, the playing of Internet games has rapidly expanded commensurate with the increased use of the Internet. Because these games provide unlimited fun and entertainment, many Internet users, including children and adolescents, are tempted to play them. However, excessive use of the Internet can be conceptualized as an addictive behavior (Young, 1998).

Persistent and recurrent use of Internet games resulting in psychological impairments or distress is defined as Internet gaming disorder (IGD) by the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5; APA, 2013). Currently, IGD is a widespread problem that affects individuals worldwide (Zhang, Amos, & McDowell, 2008). Due to the rapid increase in the number of IGD diagnoses, a comprehensive understanding of the disorder is necessary to develop effective strategies for its prevention. Furthermore, clarification of the neural mechanisms underlying the risk and protective factors for IGD will aid in the development of such strategies.

A number of protective factors for, and risk factors for the development and maintenance of, IGD have been identified. A meta-analysis of studies on Internet addiction (IA) in Korea revealed that various factors increase the likelihood of the disorder (Koo & Kwon, 2014). For example, IA has positive associations with self-related factors (e.g., escape from self), control- and regulation-related factors (e.g., attention problems), temperament factors (e.g., addiction and absorption traits), emotion- and mood-related factors (e.g., anger and aggression, and depression and anxiety), and coping factors (e.g., negative stress coping). In terms of the Big Five personality traits, increased neuroticism and decreased conscientiousness predicted IGD in a study comparing pathological gamblers with normal controls (Müller, Beutel, Egloff, & Wölfling, 2014). Additionally, psychiatric disorders such as attention deficit hyperactivity disorder (ADHD), depression, social phobia, and hostility predict the emergence of IA (Ko, Yen, Yen, Chen, & Chen, 2012).

Recently, researchers and clinicians have shifted their focus from risk factors for IGD to protective factors for the disorder, with the aim of preventing its occurrence and aiding the recovery of IGD patients. A review of longitudinal studies on adolescents and young adults demonstrated that higher levels of self-control and self-esteem, in addition to satisfaction of basic psychological needs, protect against problematic Internet use (Anderson, Steen, & Stavropoulos, 2017). Choi *et al.* (2015) reported that character strength of courage, encompasses vitality and bravery, has a negative relationship with IA. Meanwhile, resilience is receiving attention because it regarded as one of the prominent protective factors for

IGD.

Resilience can be defined as the personal qualities that enable one to thrive in the face of adversity throughout life (Connor & Davidson, 2003). Resilience involves rapid recovery from mental health disturbances following exposure to adversity (Rutten *et al.*, 2013). Resilience plays an important role in life satisfaction (Cohn, Fredrickson, Brown, Mikels, & Conway, 2009). Resilience is an important protective factor for the pathophysiology of addictive disorders (Russo, Murrough, Han, Charney, & Nestler, 2012) and is a strong protective factor against IGD (Simsek & Sali, 2014; Robertson, Yan, & Rapoza, 2018).

At present, there is a lack of research investigating the relationship between resilience and IGD and, importantly, the precise neural correlates that underlie resilience remain largely unknown. Empirical studies of resilience have focused exclusively on the behavioral and psychosocial correlates of, and contributors to, the phenomenon however, the biological correlates and/or contributors of resilience have yet to be fully explored (Cicchetti, 2010). However, Curtis and Cicchetti (2003) noted the importance of examining biological factors that contribute to resilience and suggested that adopting a biological perspective is one facet of an all-encompassing approach to understanding resilience that should encompass all levels of analysis, from molecular to cultural. Thus, novel insights into the neural mechanisms of resilience will increase understanding of this concept.

Over the past few decades, neuroimaging methods have become an increasingly important tool to study the neural correlates of adaptive and non-adaptive behaviors (van der Werff, van den Berg, Pannekoek, Elzinga, & Van Der Wee, 2013). Although there has been a recent increase in neuroimaging studies assessing the neural mechanisms that underlie resilience or IGD, respectively, little is known about the neural correlates of resilience in IGD patients. Thus, the present study used electroencephalography (EEG) to explore the neurophysiological correlates underlying the relationship between resilience and IGD. EEG involves electrophysiological recordings that show electrical activity in the brain, thus allowing baseline measurement of the brain state prior to information processing. EEG has several advantages relative to other neuroimaging tools, including a high temporal resolution, non-invasiveness, and a significantly lower cost (Wang *et al.*, 2013).

Several studies have investigated the neural mechanisms of IGD using EEG. Son *et al.* (2015) examined resting-state EEG spectral activity in patients with alcohol use disorder (AUD) or IGD and found that IGD is distinguishable from AUD due to its lower absolute fast (beta) power. In a previous study by our research group, the neural connectivity underlying IGD was studied using EEG coherence measures (Park *et al.*, 2017). EEG coherence is primarily a measure of phasic correlation (Shaw, 1984), and is widely considered to indicate the functional interaction or connectivity between two brain regions. Coherence has proved useful for detecting brain pathologies in a variety of conditions associated with neuronal dysfunction (Dafters, Duffy, O' Donnell, & Bouquet, 1999). Our study showed that patients with IGD and AUD exhibit different neurophysiological patterns of brain connectivity, and that increases in the fast-phasic synchrony of gamma coherence might be a core neurophysiological feature of IGD (Park *et al.*, 2017).

The neural correlates of resilience are also associated with specific psychological and/or cognitive phenomena, as well as psychiatric disorders including emotion dysregulation, post-traumatic stress disorder (PTSD), and major depressive disorder. A study of PTSD patients indicated that higher right prefrontal theta power during the first and last rapid eye movement (REM) periods in resilient normal participants compared with participants with PTSD. (Cowdin, Kobayashi, & Mellman, 2014). Additionally, it was reported that EEG asymmetry across central cortical regions distinguishes between high- and low-resilience children; specifically, left hemisphere activity is characteristic of maltreated children who exhibit resilience (Curtis & Cicchetti, 2007).

An event-related potential (ERP) study assessing responses to negative emotional pictures and neutral targets showed that resilience was negatively correlated with the late positive potential (LPP) response to negative emotional stimuli (Chen *et al.*, 2018). Although several EEG studies have evaluated the neural correlates of resilience, there is insufficient evidence to fully understand the neural mechanisms underlying the relationship between resilience and IGD.

To our knowledge, no studies have investigated the neurophysiological features of individuals with IGD and their relationship with resilience. Thus, the present study aimed to determine the neurophysiological correlates of resilience, via resting-state EEG spectral power and coherence analysis, in IGD patients and healthy controls (HC). Resting-state EEG activities were recorded because these could enhance the current understanding of basic brain function in IGD. Spontaneous EEG activity in the resting state has been used to identify the neural correlates of cognition and behavior (Barry, Clarke, Johnstone, Magee, & Rushby, 2007) and it has been proposed that resting-state EEG is not merely an epiphenomenon, but rather reflects the electrophysiological underpinnings of human behavior (Massar, Kenemans, & Schutter, 2014). Based on previous resting-state EEG studies, in the present study it was hypothesized that: 1) the resting-state EEG absolute power of fast waves in IGD patients and HC would be dissociable according to the degree of resilience; 2) the resting-state EEG coherence of fast waves in IGD patients and HC would be dissociable according to the degree of resilience; 3) the distinct EEG features of IGD and HC would be mediated by resilience-related clinical symptoms; 4) resilience would moderate the indirect effect of IGD on the distinct EEG features through clinical symptoms.

Particular emphasis was placed on the three fast wave bands (alpha, beta, and gamma) that were shown to be related to IGD in our previous studies (Choi *et al.*, 2013; Son *et al.*, 2015; Park *et al.*, 2017). We selected depressive symptoms and stress level as hypothesized mediators that had significant neurobiological relationships with resilience (Rutten *et al.*, 2013). Furthermore, the previous study showed that resilience had moderating effect on the association between IGD and negative psychological affects (Wisniewski *et al.*, 2015; Zhou, Zhang, Liu, & Wang, 2017). Hypothetical model of the present study was presented in figure 1.

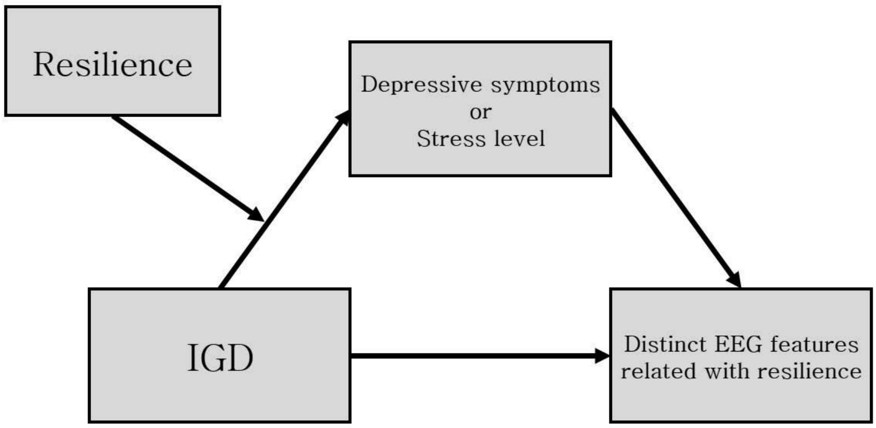

Figure 1. Hypothetical model of the present study. The present study examine whether the indirect effects of Internet gaming disorder (IGD) on resilience-related EEG features through the clinical symptoms (depressive symptoms and stress level) are moderated by resilience.

Methods

Participants

The present study initially included 76 male adults, aged between 18 and 40 years, who were recruited from SMG–SNU Boramae Medical Center in Seoul, South Korea, and the surrounding community. None of the participants had a history of significant head injury, seizure, intellectual disability [Intelligence quotient (IQ) ≥ 80], or psychotic or neurological disorders. Additionally, all participants were medication–naive and right–handed.

IGD was diagnosed by trained clinicians based on DSM–5 criteria; participants who spent more than 4 hours per day and 30 hours per week playing Internet games were included in the IGD group. Young's Internet Addiction Test (IAT) was used to assess the severity of IGD. All HC were recruited from the local community and universities, none had a history of any psychiatric disorder, and all played Internet games for less than 2 hours per day.

The data of five participants were not included in the final analyses, either because their EEG recordings were disrupted by excessive movement or the EEG channels were of poor quality ($> 100\ \mu V^2$ Sq). Thus, a total of 71 participants were included in the present analyses and categorized as IGD (n = 36) or HC (n = 35).

The institutional review board of SMG–SNU Boramae Medical

Center approved the study protocol, which adhered to the principles of the Declaration of Helsinki. All participants understood the study procedure and provided written informed consent prior to participation.

Clinical assessments

Connor–Davidson Resilience Scale

Resilience was assessed using the Connor–Davidson Resilience Scale (CD–RISC; Connor & Davidson, 2003), which is a 25–item self–report instrument that uses 5–point response scales, as follows: 0 = not true at all, 1 = rarely true, 2 = sometimes true, 3 = often true, and 4 = true nearly all of the time. The CD–RISC captures how the participant felt over the past month and total scores range from 0–100, with higher scores reflecting greater resilience. The Cronbach *alpha* coefficient was 0.967.

Young's IAT

The severity of IGD was evaluated with Young's IAT (Young, 1998; Beard & Wolf, 2001), which includes 20 items rated on 5–point scales, with the total possible score thus ranging from 20–100.

Beck Depression Inventory–II (BDI)

Beck depression inventory–II (BDI) has 21 items measuring the severity of depressive symptoms during the past 2 weeks (Beck, Steer, & Brown, 1996). Items are four points Likert scale from 0 to 3 and total scores range from 0 to 63 with higher scores indicating higher depressive symptoms.

Psychosocial Well-Being Index (PWI)

Stress level was measured with a Psychosocial Well-Being Index (PWI) which contains 45 items (Kim, 1999). PWI was developed on the basis of the General Health Questionnaire generated by Goldberg (Derose, 1997), which was designed to evaluate psychological stability among community populations and was subsequently modified to meet the characteristics of Korean populations (Kim, 1999). It contains questions about physical and psychological status over the last few weeks, covering social role performance, self-confidence, depression, sleep disturbance, anxiety, and the general well-being of respondents. Score range from 0 to 135 with higher scores indicating higher distress symptoms.

Wechsler Adult Intelligence Scale, Korean version

The Korean version of the Wechsler Adult Intelligence Scale (Yeom, Park, Oh, & Lee, 1992) was administered to all participants to estimate IQ levels.

EEG recoding

Each participant was seated on a comfortable chair in an isolated sound-shielded room with dimmed lights, and then underwent EEG recording in a resting state that lasted for 10 min (4 min with eyes closed, 2 min with eyes open, and 4 min with eyes closed). All participants were instructed to avoid moving or becoming drowsy. All EEG activity was recorded using a 64-channel Quik-cap (Compumedics Neuroscan, El Paso, TX, USA) based on the modified international 10/20 system, in conjunction with vertical and horizontal electrooculograms (EOGs) and one bipolar reference electrode connected to the mastoid. All EEG acquisitions were done using SynAmps 2 (Compumedics, Abbotsford, Australia) and the Neuroscan system (Scan 4.5; Compumedics). EEG signals were amplified at a sampling rate of 1,000 Hz using a 0.1–100 Hz online bandpass filter and a 0.1–50 Hz offline bandpass filter, while electrode impedance was kept below 5 kΩ.

All acquired EEG data were processed with NeuroGuide software (ver. 2.6.1; Applied Neuroscience, St. Petersburg, FL, USA). For the analyses, 19 of the 64 channels were selected according to the montage set with linked ear references from the NeuroGuide, as follows: FP1, F3, F7, Fz, FP2, F4, F8, T3, C3, Cz, T4, C4, T5, P3, O1, Pz, T6, P4 and O2 (Fig. 2). All EEG recordings under eyes-closed conditions were selected and artifacts were removed using the artifact rejection toolbox in NeuroGuide and based on visual inspection. Finally, the artifact-free epochs, ranging in length from 24.09–323.99 s, were averaged for each electrode. The average epoch length was 124.59 ± 66.92 s in the IGD group and 139.72 ± 52.30 s in the HC group; one-way analysis of variance (ANOVA; P = 0.291) revealed that the epoch lengths of the two groups did not differ significantly. Visualizations were performed with Matlab software (MathWorks, Natick, MA, USA).

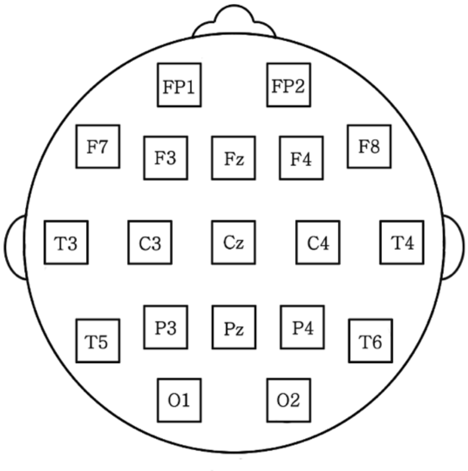

Figure 2. Representation of the 19 electrodes in the absolute power analyses.

Power spectral analyses

In each of the three fast frequency bands, alpha (8.0–12.0 Hz), beta (12.0–25.0 Hz), and gamma (30.0–40.0 Hz), absolute power (μV^2) was calculated using fast Fourier transform (FFT) and averaged using the NeuroGuide spectral analysis system. The specific FFT parameters were as follows: epoch = 2 s, sample rate = 128 samples/s (256 digital timepoints), and resolution 0.5 Hz, with a cosine taper window used to minimize leakage. The 19 selected electrodes were divided into three regions as follows (Barry *et al.*, 2007): frontal (FP1, F3, F7, Fz, FP2, F4, F8), central (T3, C3, Cz, T4, C4) and posterior (T5, P3, O1, Pz, T6, P4, O2). To determine the variation in absolute power by hemisphere, the EEG signals were categorized into the left (FP1, F3, F7, T3, C3, T5, P3, O1) and right hemisphere (FP2, F4, F8, T4, C4, T6, P4, O2).

Coherence analyses

Coherence values were computed for all pairwise combinations of the 19 channels, for each of the three frequency bands (alpha, beta, and gamma), using NeuroGuide software (R. Thatcher, McAlaster, Lester, Horst, & Cantor, 1983). Coherence was defined using the following equation:

$$\Gamma^{2}_{xy}(f) = \frac{(G_{xy}(f)^2)}{(G_{xx}(f)G_{yy}(f))} \;,$$

where $G_{xy}(f)$ is the cross-power spectral density and $G_{xx}(f)$ and $G_{yy}(f)$ are the respective autopower spectral densities. The computational procedure to obtain coherence involved first computing the power spectra for x and y and then computing the normalized cross-spectra. Because complex analyses are involved in this process, the cospectrum ('r' for real) and quadspectrum ('q' for imaginary) were produced. Subsequently, coherence was computed as follows (R. W. Thatcher, North, & Biver, 2005):

$$\Gamma^{2}_{xy} = \frac{r_{xy}^2 + q_{xy}^2}{G_{xx}G_{yy}}.$$

A total of 171 intrahemispheric and interhemispheric pairwise combinations of electrodes were obtained and intrahemispheric coherence was examined using the F3-C3, F3-T3, F3-P3, C3-T3, C3-P3, and T3-P3 electrode pairs in the left hemisphere and the F4-C4, F4-T4, F4-P4, C4-T4, C4-P4, and T4-P4 electrode pairs in the right hemisphere. Interhemispheric coherence was calculated between electrode pairs F3-F4, C3-C4, T3-T4, and P3-P4 (Fig. 3; Kam, Bolbecker, O'Donnell, Hetrick, & Brenner, 2013).

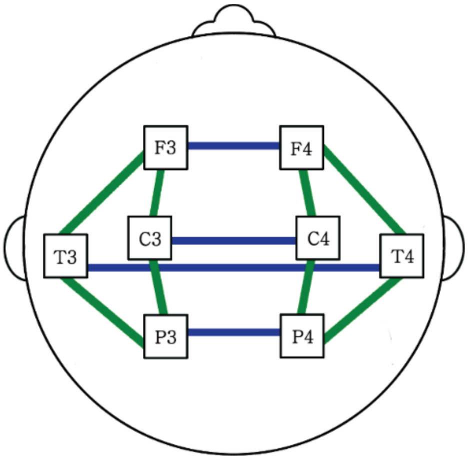

Figure 3. Representation of electrode pairs assessed in the coherence analyses. Green and blue lines indicate intra- and interhemispheric coherence values, respectively.

Procedure

To identify the effects of resilience on EEG activity in IGD patients, the IGD group was divided into two subgroups based on the degree of resilience, as determined by the CD-RISC: IGD patients with low resilience (LowRe-IGD, n = 16; score range: 8-43, which was below the 50th percentile) and IGD patients with high resilience (HighRe-IGD, n = 19; score range: 44-49, which was above the 50th percentile). Subsequently, four studies were conducted to determine the EEG correlates of resilience: Study 1) compared absolute power among the HighRe-IGD, LowRe-IGD, and HC groups; Study 2) compared intra- and interhemispheric coherence among the LowRe-IGD, HighRe-IGD, and HC groups; and Study 3) determined whether clinical features (depressive symptoms and stress level) had mediating effects on the relationship between IGD and distinct EEG features identified in Studies 1 and 2. Study 4) determined whether the indirect effects of IGD on resilience-related EEG features through the clinical symptoms were moderated by resilience.

Statistical analyses

First, comparisons of demographic and clinical variables among the groups (IGD vs. HC and LowRe-IGD vs. HighRe-IGD vs. HC) were performed using one-way ANOVA. Next, a generalized estimating equation (GEE) has been conducted to analyze the characteristics of EEGs in each band. GEEs are employed to consider unknown and possible correlations between repeated or multiple outcomes from the same subjects (Claassen *et al.*, 2004; Ziegler, 2011). All statistical analyses were performed using SPSS software (version 23.0, IBM, Armonk, NY, USA).

In Study 1, group (LowRe-IGD, HighRe-IGD, HC), region (frontal, central, posterior), hemisphere (left, right), and their interaction effects were tested in each band with a GEE. Age, years of education, and IQ were adjusted for because these characteristics differed among the groups. In Study 2, intrahemispheric and interhemispheric coherence values were assessed according to the following factors: 1) intrahemispheric coherence: group (LowRe-IGD, HighRe-IGD, HC) × region (fronto-central, fronto-temporal, fronto-parietal, centro-temporal, centro-parietal, temporo-parietal) × hemisphere (left, right) and 2) interhemispheric coherence: group

(LowRe-IGD, HighRe-IGD, HC) × region (frontal, central, temporal, parietal). Years of education and IQ were adjusted for because these characteristics differed among the groups.

In study 3 and 4, we performed Pearson's correlation analyses to determine the relationships among resilience (CD-RISC scores), clinical data (depressive symptoms and stress level), and EEG features that showed significant main or interaction effects in Studies 1 and 2. The PROCESS macro for SPSS (Hayes, 2013), a bootstrapping approach, was employed to analyze the mediating effects, moderating effects, and conditional indirect effects (moderated mediation). First, simple mediation models (model 4) were tested to determine whether clinical features mediated the relationship between IGD on the resilience-related EEG feature in the entire cohort. Second, simple moderation models (model 1) were employed to confirm how IGD interacted with resilience and clinical symptoms. Third, moderated mediation models (model 7) were evaluated to determine whether the indirect effect of IGD on the distinct EEG features through the depressive symptoms and stress level were moderated by resilience. Significance was determined using bias-corrected 95% confidence intervals (BCa CI) by bootstrapping using 5000 resamples, and it was indicated when CI did not include zero. We used the Sobel test (Z) to examine the indirect effect size of mediating models. Based on the pick-a-point method, conditional effects at plus and minus one standard deviation around the mean of resilience were estimated. (Hayes, 2013). Continuous variables were mean-centered to reduce any multicollinearity, and IQ and years of education were controlled in mediation, moderation, and moderated mediation analyses.

For all analyses, P-values < 0.05 were considered to indicate statistical significance. When Bonferroni-corrected post-hoc comparisons were performed, P-values < 0.0167 were considered to indicate statistical significance.

Results

Demographic and clinical data

The demographic and clinical data of the IGD and HC groups are compared in Table 1. The groups significantly differed in terms of years of education and mean time spent using the internet for playing games on weekdays and weekends (all $P < 0.001$), but there was no significant difference in age. The average IAT score in the IGD group was 64.57 ± 15.37, the mean time spent playing Internet games per weekday was 6.85 ± 3.94 hours, and the mean time spent playing Internet games per weekend day was 8.79 ± 3.88 hours. In terms of the clinical data, IGD patients had higher BDI and PWI scores than HC ($P < 0.001$) but the mean resilience score of the HC group (74.14 ± 8.44) was significantly higher than that of the IGD patients (46.23 ± 21.68; $P < 0.001$). IGD patients showed lower IQ score than HC ($P < 0.001$).

To identify potential relationships between resilience and IGD, the IGD patients were divided into two groups (LowRe- and HighRe-IGD) according to CD-RISC score; the demographic and clinical characteristics are shown in Table 2. CD-RISC score significantly differed among the groups, where the LowRe-IGD group had a lower score than the HighRe-IGD and HC groups (LowRe-IGD: 26.00 ± 12.81; HighRe-IGD: 63.26 ± 9.02; HC: 74.14 ± 8.44; $P < 0.001$).

The severity of IGD in the LowRe−IGD group was significantly higher than that in the HighRe−IGD and HC groups ($P < 0.001$). In terms of clinical data, LowRe−IGD showed lower BDI and PWI scores than HighRe−IGD and HC (all $P < 0.001$).

Table 1. Demographic and clinical characteristics between IGD and HC groups

	IGD (n = 35) Mean ± S.D	HC (n = 36) Mean ± S.D	*F*	*P*
Demographic data				
Age	23.94 ± 5.47	25.14 ± 3.60	1.190	.279
Education (years)	12.86 ± 1.70	14.75 ± 1.87	19.849***	< .001
Game usage in weekday (per hour)	6.85 ± 3.94	0.88 ± 1.14	70.217***	< .001
Game usage in weekend (per hour)	8.79 ± 3.88	1.06 ± 1.01	123.200***	< .001
Clinical data				
IAT	64.57 ± 15.37	29.11 ± 7.09	157.274***	< .001
CD−RISC	46.23 ± 21.68	74.14 ± 8.44	51.621***	< .001
BDI	18.57 ± 12.20	3.00 ± 2.99	55.304***	< .001
PWI	68.29 ± 30.34	28.86 ± 12.75	51.454***	<.001
IQ	107.31 ± 14.29	119.75 ± 10.45	17.586***	< .001

Note. IGD = Internet gaming disorder; HC = healthy controls; S.D = standard deviation; IAT = Young's Internet addiction test; CD−RISC = Connor−Davidson resilience scale; BDI = Beck depression inventory−Ⅱ; PWI = Psychosocial Well−Being Index; IQ = intelligence quotient; $P < 0.001$***.

. Table 2. Demographic and clinical characteristics among LowRe−IGD, HighRe−IGD, and HC groups

	LowRe−IGD (n = 16) Mean ± S.D	HighRe−IGD (n = 19) Mean ± S.D	HC (n = 36) Mean ± S.D	*F*	*P*	*Post hoc.*
Demographic data						
Age	22.13 ± 5.56	25.47 ± 5.04	25.14 ± 3.60	3.037	.055	
Education (years)	12.44 ± 1.15	13.21 ± 2.02	14.75 ± 1.87	10.833***	< .001	L, H < HC
Game usage in weekday (per hour)	8.75 ± 3.99	5.17 ± 3.11	0.88 ± 1.14	50.856***	< .001	HC < H < L
Game usage in weekend (per hour)	10.25 ± 3.53	7.55 ± 3.80	1.06 ± 1.01	72.937***	< .001	HC < H < L
Clinical data						
IAT	72.63 ± 14.18	57.79 ± 13.13	29.11 ± 7.09	104.552***	< .001	HC < H < L
CD−RISC	26.00 ± 12.81	63.26 ± 9.02	74.14 ± 8.44	137.127***	< .001	L < H < HC
BDI	27.94 ± 9.88	10.68 ± 7.48	3.00 ± 2.99	84.156***	< .001	HC < H < L
PWI	93.25 ± 17.27	47.26 ± 21.67	28.86 ± 12.75	83.903***	< .001	HC < H < L
IQ	102.38 ± 11.40	111.47 ± 15.41	119.75 ± 10.45	11.718***	< .001	L < HC

Note. LowRe−IGD and L = Internet gaming disorder with low resilience; HighRe−IGD and H = Internet gaming disorder with high resilience; HC = healthy controls; S.D = standard deviation; n.s = not significant; IAT = Young's Internet addiction test; CD−RISC = Connor−Davidson resilience scale; BDI = Beck Depression inventory−Ⅱ; PWI = Psychosocial Well−Being Index; IQ = intelligence quotient; P < 0.001***; The Bonferroni−corrected post hoc comparison was used (P < 0.0167).

Absolute power

The absolute power values for each frequency band are presented in Table 3. Figure 4 illustrates the scalp topography of each group in terms of absolute power. For the alpha band, there was a significant group effect (x^2 = 9.860, P = 0.007), where the LowRe-IGD group showed lower absolute power compared to the HC group (P = 0.005). However, the GEE results did not show group × region, group × hemisphere, or group × region × hemisphere interaction effects.

For the beta band, the group × hemisphere interaction effect was significant (x^2 = 10.252, P = 0.006) but there was no group difference. For the gamma band, there were significant group × hemisphere (x^2 =7.409, P = 0.025) and group × region × hemisphere (x^2 = 12.777, P = 0.047) interaction effects but no group differences were revealed by the Bonferroni post-hoc analyses.

Table 3. Model effects for absolute power among LowRe−IGD, HighRe−IGD, and HC groups

Absolute power (μV^2)	Wald x^2	*df*	*P*	*Post hoc.*
Alpha				
Group	9.860**	2	.007	L < HC
Group × Region	0.615	4	.961	
Group × Hemisphere	1.105	2	.576	
Group × Region × Hemisphere	5.145	6	.525	
Beta				
Group	0.411	2	.814	
Group × Region	1.184	4	.881	
Group × Hemisphere	10.252**	2	.006	n.s
Group × Region × Hemisphere	6.467	6	.373	
Gamma				
Group	1.488	2	.475	
Group × Region	2.583	4	.630	
Group × Hemisphere	7.409*	2	.025	n.s
Group × Region × Hemisphere	12.777*	6	.047	n.s

Note. L = Internet gaming disorder with low resilience; HC = healthy controls; $P < 0.05$*, $P < 0.01$**; n.s = not significant; The Bonferroni−corrected post hoc comparison was used ($P < 0.0167$).

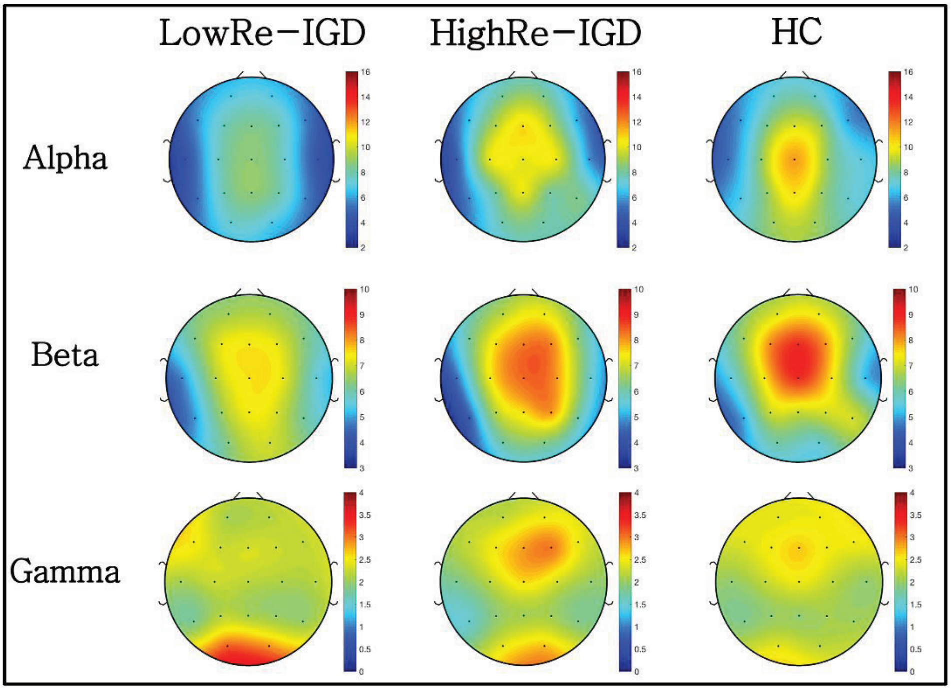

Figure 4. Topographical maps of absolute power in the Internet gaming disorder with low resilience (LowRe−IGD), Internet gaming disorder with high resilience (HighRe−IGD), and health controls (HC) groups. The scale shows the μV^2 values for absolute power; red represents higher values and blue represents lower values. The LowRe−IGD group exhibited lower absolute power in the alpha band compared to the HC group.

Intrahemispheric coherence

Analyses of intrahemispheric coherence revealed that there were significant group ($\boldsymbol{x}^2$ = 13.515, P = 0.001) and group × hemisphere ($\boldsymbol{x}^2$ = 7.358, P = 0.025) interaction effects for the alpha band (Table 4). The LowRe−IGD group showed greater alpha intrahemispheric coherence than the HighRe−IGD (P = 0.001) and HC (P = 0.009) groups. Additionally, the higher alpha coherence in the LowRe−IGD group was primarily evident in the right hemisphere (HighRe−IGD: P < 0.001; HC: P = 0.001).

Although there was a significant group × region interaction effect for beta intrahemispheric coherence ($\boldsymbol{x}^2$ = 26.246, P = 0.001), there were no group differences (all P > 0.0167). Regarding intrahemispheric coherence in the gamma band, no significant main or interaction effects were found.

Table 4. Model effects for intrahemispheric coherence among LowRe−IGD, HighRe−IGD, and HC groups

Intrahemispheric coherence	Wald x^2	*df*	*P*	*Post hoc.*
Alpha				
Group	13.515**	2	.001	H, HC < L
Group × Region	10.983	10	.359	
Group × Hemisphere	7.358*	2	.025	Right : H, HC < L
Group × Region × Hemisphere	6.590	15	.968	
Beta				
Group	0.908	2	.635	
Group × Region	26.246**	10	.003	n.s
Group × Hemisphere	2.745	2	.254	
Group × Region × Hemisphere	4.377	15	.996	
Gamma				
Group	1.268	2	.530	
Group × Region	7.083	10	.718	
Group × Hemisphere	0.470	2	.791	
Group × Region × Hemisphere	2.584	15	.999	

Note. L = Internet gaming disorder with low resilience; H = Internet gaming disorder with high resilience; HC = healthy controls; n.s = not significant; $P < 0.05$*, $P < 0.01$**; The Bonferroni−corrected post hoc comparison was used ($P < 0.0167$).

Interhemispheric coherence

Table 5 shows the interhemispheric coherence data. In the alpha band, there was a significant main effect of group (x^2 = 9.836, P = 0.007), where the LowRe-IGD group exhibited higher alpha coherence compared to the HC group (P = 0.008). There was no group × region interaction effect in the alpha band. In the beta and gamma bands, there were no main effects of group, and no group × region, group × hemisphere, or group × region × hemisphere interaction effects for interhemispheric coherence.

Table 5. Model effects for interhemispheric coherence among LowRe-IGD, HighRe-IGD, and HC groups

Interhemispheric coherence	Wald x^2	*df*	*P*	*Post hoc.*
Alpha				
Group	9.836**	2	.007	HC < L
Group ×Region	2.544	6	.863	
Beta				
Group	4.582	2	.101	
Group ×Region	0.953	6	.987	
Gamma				
Group	1.386	2	.500	
Group ×Region	0.990	6	.986	

Note. L = Internet gaming disorder with low resilience; HC = healthy controls; P < 0.01**; The Bonferroni-corrected post hoc comparison was used (P < 0.0167).

Correlation analyses

In the IGD and HC groups, resilience showed differential associations with EEG features. Furthermore, correlation analyses of CD−RISC scores and EEG features that were significant in the GEE analyses revealed significant group differences in alpha absolute power, alpha intrahemispheric coherence (in all electrode pairs), alpha coherence (in the right hemisphere), and alpha interhemispheric coherence (Table 6). The mean value of each EEG variable was included in the correlation analysis.

In the overall cohort, there was a significant relationship between CD−RISC score and alpha coherence in the right hemisphere ($r = -0.264$, $P = 0.026$); however, this relationship differed between the IGD patients and HC, where the IGD group showed a negative correlation ($r = -0.435$, $P = 0.009$) and the HC group a positive correlation ($r = 0.440$, $P = 0.007$).

BDI was correlated with alpha coherence in the whole electrode pairs ($r = 0.278$, $P = 0.019$) and electrodes in the right hemisphere ($r = 0.337$, $P = 0.004$), and interhemispheric coherence ($r = 0.250$, $P = 0.036$) in the overall cohort. There were significant positive correlations between BDI and alpha coherence in IGD patients (all electrode pairs: $r = 0.373$, $P = 0.027$; right hemisphere: $r = 0.417$, $P = 0.013$), whereas HC group had no significant correlations (all electrode pairs: $r = 0.026$, $P = 0.880$; right hemisphere: $r = 0.114$, $P = 0.509$). PWI had positive correlations with alpha coherence in the right hemisphere in the overall cohort ($r = 0.318$, $P = 0.007$) and IGD patients ($r = 0.461$, $P = 0.005$).

Table 6. Pearson's correlation analysis between clinical features and EEG features

Overall (n= 71)	CD-RISC	BDI	PWI
CD-RISC	1		
BDI	-0.793***	1	
PWI	-0.880***	0.888***	1
Alpha absolute power	0.138	-0.120	-0.166
Alpha intrahemispheric coherence (all electrode pairs)	-0.166	0.278*	0.211
Alpha intrahemispheric coherence (right hemisphere)	-0.264*	0.337**	0.318**
Alpha interhemispheric coherence	-0.192	0.250*	0.179
IGD (n= 35)	**CD-RISC**	**BDI**	**PWI**
CD-RISC	1		
BDI	-0.718***	1	
PWI	-0.864***	0.834***	1
Alpha absolute power	0.291	-0.165	-0.293
Alpha intrahemispheric coherence (all electrode pairs)	-0.268	0.373*	0.311
Alpha intrahemispheric coherence (right hemisphere)	-0.435**	0.417*	0.461**
Alpha interhemispheric coherence	-0.215	0.272	0.213
HC (n= 36)	**CD-RISC**	**BDI**	**PWI**
CD-RISC	1		
BDI	0.114	1	
PWI	-0.357*	0.611**	1
Alpha absolute power	-0.035	-0.195	-0.091
Alpha intrahemispheric coherence (all electrode pairs)	0.273	0.026	-0.118
Alpha intrahemispheric coherence (right hemisphere)	0.440**	0.114	-0.151
Alpha interhemispheric coherence	0.149	-0.041	-0.202

Note. CD-RISC = Connor-Davidson resilience scale; BDI = Beck Depression inventory-Ⅱ; PWI = Psychosocial Well-Being Index; IGD = Internet gaming disorder; HC = healthy controls; The mean value of each EEG variable was included; $P < 0.05$*, $P < 0.01$**, $P < 0.001$***.

Tests of mediation

We examined the mediating roles of depressive symptoms and stress level on the relationship between IGD and alpha coherence in the right hemisphere via PROCESS macro (Table 7). The simple mediation analysis with depressive symptoms as a mediator showed that IGD had no total effect (B = 3.885, S.E = 3.452, P = 0.264) and direct effect (B = −2.806, S.E = 3.664, P = 0.446) on alpha coherence in the right hemisphere. However, the effect of IGD to depressive symptoms (B = 15.571, S.E = 2.094, P < 0.001) and that of depressive symptoms to alpha coherence in the right hemisphere had positive associations (B = 0.580, S.E = 0.159, P = 0.001). The Sobel test indicated significant indirect effect of depressive symptoms (Z=3.254 P = 0.001). It was confirmed by the bootstrap results with 5,000 re−samples, with indirect effect of 9.031 and 95% bias−corrected and accelerated bootstrap interval (BCa CI) around this value not containing zero [4.042, 16.109].

In the model with stress level as a mediator, the total effect (B = 3.885, S.E = 3.452, P = 0.264) and direct effect were not significant (B = −2.227, S.E = 3.840, P = 0.564). However, a significant effect of stress level regressed on IGD (B = 39.425, S.E = 5.496, P < 0.001) and also of alpha coherence in the right hemisphere regressed on stress level (B = 0.179, S.E = 3.840, P = 0.004) were found. The Sobel test indicated significant indirect effects of stress level (Z = 2.757, P = 0.006). Bootstrap results confirmed this indirect effect of 7.064 and BCa CI around [1.994, 14.007]. In other words, the simple mediation analysis yielded the evidence of a positive indirect effect of IGD on alpha coherence in the right hemisphere through depressive symptoms and stress level, with IGD linked to more depressive symptoms and higher stress level related to greater alpha coherence in the right hemisphere.

Table 7. Mediation model of IGD and alpha coherence in the right hemisphere through depressive symptoms and stress level (n= 71, bootstrap = 5000)

Path	B	S.E	95% CI	
			LLCI	ULCI
Direct effect				
IGD → depression	15.571***	2.094	11.394	19.749
IGD → alpha coherence in the right hemisphere	−2.806	3.664	−10.122	4.509
BDI → alpha coherence in the right hemisphere	0.580**	0.159	0.263	0.897
IGD → stress level	39.425***	5.496	28.460	50.389
IGD → alpha coherence in the right hemisphere	−2.227	3.840	−9.893	5.439
Stress level → alpha coherence in the right hemisphere	0.179**	0.059	0.061	0.298
	B	Boot S.E	95% BCa CI	
			LLCI	ULCI
Indirect effect				
Depression	9.031	3.052	4.042	16.109
Stress	7.064	2.562	1.994	14.007

Note. S.E = standard error; CI = confidence intervals; LLCI = lower limit confidence intervals; ULCI = upper limit confidence intervals; 95% BCa CI = 95% bias-corrected and accelerated bootstrap interval; IGD = Internet gaming disorder; Resilience, depressive symptoms, and stress level were assessed by Connor-Davidson resilience scale (CD-RISC), Beck depression inventory-Ⅱ (BDI), and Psychosocial Well-Being Index (PWI) respectively; IQ and years of education were controlled; $P < 0.01$**, $P < 0.001$***.

Tests of moderated mediation

Before conducting moderated mediation analyses, the moderating effects of resilience on the relationship between IGD and depressive symptoms and stress level were evaluated. The model showed that interaction effects of resilience and IGD on clinical symptoms were significant (depressive symptoms: B = −0.444, S.E = 0.138, P = 0.002; stress level: B = −0.444, S.E = 0.138, P = 0.028). Significant conditional effects of IGD on clinical symptoms were observed at the low resilience (mean − 1 S.D; depressive symptoms: B = 19.959, boot S.E = 4.790, P < 0.001; stress level: B = 29.265, boot S.E = 10.363, P = 0.006) and moderate resilience (mean; depressive symptoms: B = 10.412, boot S.E = 2.440, P < 0.001; stress level: B = 14.890, boot S.E = 5.280, P = 0.006). On the other hand, there was no significant conditional effect of IGD on clinical symptoms in participants with high resilience (mean − 1 S.D; depressive symptoms: P > 0.05); i.e., severe depressive symptoms and higher stress level compared with HC were presented in the IGD with lower resilience and were not evident in the IGD with higher resilience (Fig. 5).

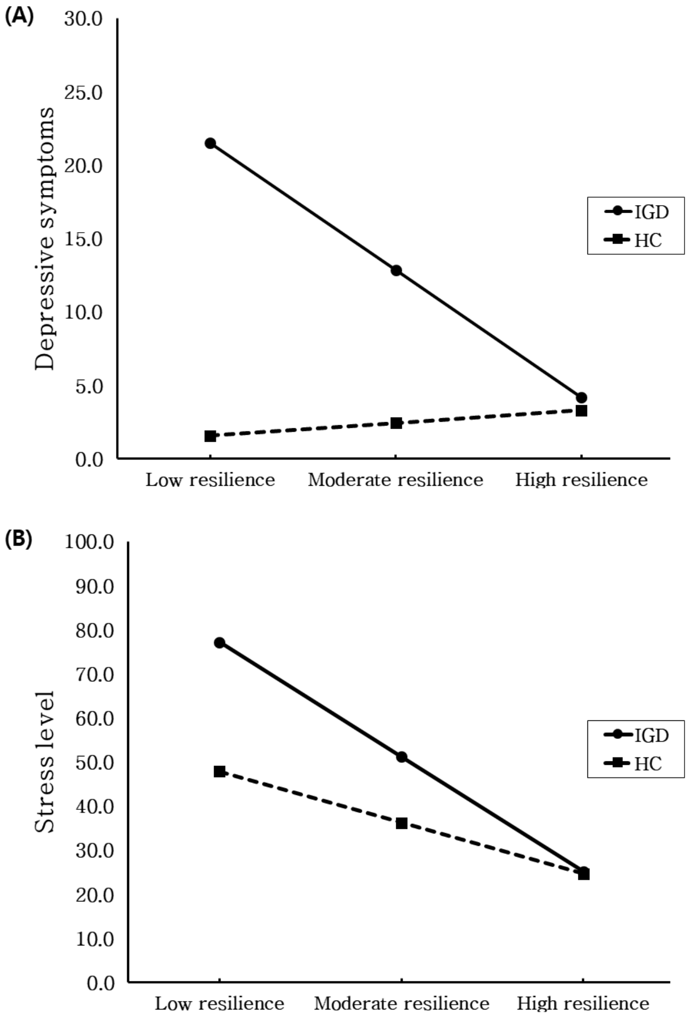

Figure 5. The interaction effects of Internet gaming disorder (IGD) and resilience on (A) depressive symptoms (B) stress level. Greater depressive symptoms and higher stress level than healthy controls (HC) were presented only in IGD patients with low (mean − 1 S.D) and moderate resilience (mean), which it did not correspond to those with high resilience (mean + 1 S.D). Resilience, depressive symptoms, and stress level were assessed by Connor−Davidson resilience scale (CD−RISC), Beck depression inventory−II (BDI), and Psychosocial Well−Being Index (PWI) respectively.

Next, the moderated mediation analysis examined the potential conditional effects of resilience on the mediation process. A significant indirect effect was found for IGD on alpha coherence in the right hemisphere through depressive symptoms (Table 8). The overall moderated mediation model was supported with the index of moderated mediation (B = −0.258, S.E. = 0.094, BCa CI [−0.462, −0.093]). An effect of IGD on alpha coherence in the right hemisphere was not significant (B = −2.806, S.E = 3.664, P =446). However, moderated mediation effect of depressive symptoms indicated that the mediating effect was conditional on alpha coherence in the right hemisphere. Depressive symptoms mediated IGD on alpha coherence in the right hemisphere at low (mean − 1 S.D; B = 11.576, boot S.E = 3.958, BCa CI [4.507, 19.983]) and moderate (mean; B = 6.039, boot S.E = 2.266, BCa CI [2.377, 11.375]) degree of resilience.

Moderated mediation model with stress level (mediator), it was significant that the indirect effect of IGD on alpha coherence in the right hemisphere through the stress level was moderated by resilience (Index of moderated mediation = −0.120, S.E. = 0.075, BCa CI [−0.326, −0.019]; Table 9). There were significant positive associations between IGD and alpha coherence in the right hemisphere through the stress level only at low (mean − 1 S.D; B = 5.244, boot S.E = 2.916, BCa CI [1.271, 13.060]) and moderate (mean + 1 S.D; B = 2.668, boot S. E. = 1.557, BCa CI [0.584, 6.901]) level of resilience.

Table 8. Moderated mediation model with IGD, alpha coherence in the right hemisphere, and depressive symptoms (n= 71, bootstrap = 5000)

	B	S.E	95% CI	
			LLCI	ULCI
Mediator variable model (Y = depression)				
IGD (predictor)	10.412***	2.441	5.541	15.284
Resilience (Moderator)	0.040	0.128	−0.216	0.297
IGD × Resilience	−0.444**	0.138	−0.720	−0.169
Dependent variable model (Y = alpha coherence in the right hemisphere)				
Depression (Mediator)	0.580**	0.159	0.263	0.897
IGD (predictor)	−2.806	3.664	−10.122	4.509

	B	Boot S.E	95% BCa CI	
			LLCI	ULCI
Conditional indirect association at different values of the resilience (moderator)				
Low (Mean – 1 S.D)	11.576	3.958	4.507	19.983
Moderate (Mean)	6.039	2.266	2.377	11.375
High (Mean + 1 S.D)	0.502	1.665	−2.072	4.833
Moderated mediation effect	−0.258	0.094	−0.463	−0.093

Note. S.E = standard error; CI = confidence intervals; LLCI = lower limit confidence intervals; ULCI = upper limit confidence intervals; 95% BCa CI = 95% bias−corrected and accelerated bootstrap interval; IGD = Internet gaming disorder; Resilience and depressive symptoms were assessed by Connor−Davidson resilience scale (CD−RISC) and Beck depression inventory−Ⅱ (BDI) respectively; Mean score of CD−RISC was 60.38 and standard deviation (S.D) was 21.48. IQ and years of education were controlled; $P < 0.01$**, $P < 0.001$***.

Table 9. Moderated mediation model with IGD, alpha coherence in the right hemisphere, and stress level (n= 71, bootstrapping = 5000)

	B	S.E	95% CI	
			LLCI	ULCI
Mediator variable model (Y = stress level)				
IGD (predictor)	14.891**	5.280	4.351	25.430
Resilience (Moderator)	−0.540	0.278	−1.094	0.014
IGD × Resilience	−0.669*	0.299	−1.265	−0.073
Dependent variable model (Y = alpha coherence in the right hemisphere)				
Stress level (Mediator)	0.179**	0.059	0.061	0.298
IGD (predictor)	−2.227	3.840	−9.893	5.439

	B	Boot S.E	95% BCa CI	
			LLCI	ULCI
Conditional indirect association at different values of the resilience (moderator)				
Low (Mean – 1 S.D)	5.244	2.916	1.271	13.060
Moderate (Mean)	2.668	1.557	0.584	6.901
High (Mean + 1 S.D)	0.092	1.252	−2.159	2.962
Moderated mediation effect	−0.120	0.075	−0.326	−0.019

Note. S.E = standard error; CI = confidence intervals; LLCI = lower limit confidence intervals; ULCI = upper limit confidence intervals; 95% BCa CI = 95% bias−corrected and accelerated bootstrap interval; IGD = Internet gaming disorder; Resilience and stress level symptoms were assessed by Connor−Davidson resilience scale (CD−RISC) and Psychosocial Well−Being Index (PWI) respectively; Mean score of CD−RISC was 60.38 and standard deviation (S.D) was 21.48. IQ and years of education were controlled; P < 0.01**, P < 0.001***.

Discussion

The primary goal of the present study was to investigate the relationship between resilience and IGD pathology via resting-state EEG power and functional connectivity analyses. IGD patients exhibited lower resilience than HC; furthermore, IGD patients with low resilience showed decreased alpha absolute power and increased coherence, especially in the right hemisphere, compared to IGD patients with high resilience and HC. Additionally, resilience had a moderating effect on the relationship between IGD and clinical symptoms including depressive symptoms and stress level that were related with resilience. Importantly, there were indirect effects of IGD on alpha coherence in the right hemisphere through depressive symptoms and level of stress, which those indirect effects were moderated by the degree of resilience.

As hypothesized, EEG absolute power differed according to the degree of resilience. It was known that frontal EEG alpha asymmetry is related to emotional regulation (Goodman, Rietschel, Lo, Costanzo, & Hatfield, 2013). These authors reported that EEG alpha asymmetry during a stress-inducing task explained a significant proportion of variance in emotional regulation, i.e., more than could be accounted for by resting-state EEG asymmetry. That is, this frontal alpha EEG asymmetry in the resting state failed to account for significant variability in emotional regulation. Thus, this study suggests that the subjects who exhibit higher levels of frontal asymmetry, which is indicative of decreased alpha power in the right compared to the left hemisphere, have superior emotional regulatory control under conditions of stress. In the present study, IGD patients with low resilience exhibited decreased alpha power, even in a relaxed state. Although IGD patients with low resilience showed decreased alpha power relative to HC, this did not differ by region or hemisphere, it is possible that IGD patients have deficits in emotional regulation.

Resilient individuals use adaptive strategies that elicit positive emotions to regulate emotions in negative situations (Tugade & Fredrickson, 2007). When low- and high-resilience individuals experience similar levels of cardiovascular negative emotional arousal in response to a stressor, the high-resilience individuals exhibit faster cardiovascular recovery. Yen *et al.* (2017) showed that individuals with IGD show less emotional regulation, use fewer reappraisal strategies, and tend to suppress emotions more so than the average person. Additionally, lower levels of cognitive reappraisal, and higher levels of expressive suppression, are associated with depression, anxiety, and hostility in subjects with IGD. Taken together, these findings suggest that decreased alpha power is associated with low resilience in IGD patients. However, alpha power was not correlated with resilience, further study with large cohort will be necessary to examine the specific associations among alpha power and resilience in the IGD patients.

The present study observed that indirect effects of IGD on alpha coherence in the right hemisphere through depressive symptoms and stress level were significant in IGD patients with lower and moderate resilience level. In other words, IGD patients with lower resilience showed severe depressive symptoms and higher stress level, which it was related with greater alpha coherence in the right hemisphere. Resilience is typically studied in PTSD patients because this trait plays an important role in preventing the development of the disorder after marked acute or chronic stress (Kautz, Charney, & Murrough, 2017). An EEG study of PTSD patients found that individuals with PTSD have increased alpha coherence between the precuneus and right inferior parietal lobe, where these abnormal neurophysiological patterns reflect symptoms such as high persistent intrusive thoughts, difficulties in emotional regulation, fragmentation of traumatic memories, and working memory deficits. Furthermore, it is well known that IGD is associated with anxiety, depression, and stressful life events (Yan, Li, & Sui, 2014; Younes *et al.*, 2016).

A study on children revealed that males who experienced abuse (psychological neglect, physical neglect, paternal physical violence, and/or sexual violence) in the past year were more likely than their peers to have relatively high levels of PTSD and IA (Hsieh *et al.*, 2016). Thus, increased alpha coherence in the right hemisphere of IGD patients may indicate that non-resilient individuals have trouble dealing with stress and negative emotions associated with unpleasant past events, which in turn would predispose them to addiction to

Internet games. In other words, individuals may try to "hide" in the virtual world (Internet games) to avoid or reduce negative affect, or due to difficulties in coping with acute or chronic stress and negative emotions. Thus, clinicians should pay attention to dysfunctional emotional regulation and stress coping when treating IGD patients with lower resilience and their altered alpha coherence in the right hemisphere.

We found significant group effects on beta and gamma absolute power and beta intrahemispheric coherence, whereas there were no group differences among three groups. It is not concordant with previous studies that reported IGD patients had reduced beta power and greater gamma power and coherence (Choi et al., 2013; Park et al., 2017; Son et al., 2015). However, the inconsistent results with previous studies may be explained several reasons. First, the present study tries to explore neurophysiological features that related with resilience in IGD patients. Thus, changed EEG activity in the beta or gamma bands indicates more homogeneous features of the IGD pathology, while alpha coherence in the right hemisphere shows us that it is distinct feature associated with resilience in IGD patients. Second, there is possibility that it may get affected by our small cohort of IGD patients. There are significant main and interaction effects in both bands in the present study, further study with large cohort will be needed to clear these inconsistent results.

The present study had several limitations that should be noted. First, only male participants were assessed. Second, the sample size was insufficient to be deemed representative of all IGD patients; because these issues may limit the generalizability of the results, further investigations with larger sample sizes, and including female participants, will be necessary. Third, comorbidities in the IGD patients were not controlled for. However, it has been reported that resilience is strongly related with depression, anxiety, and stress (Wagnild, 2009); thus, we suggested moderated mediation models with these factors (depressive symptoms and stress level) which can be regarded as integral to resilience. Despite these limitations, the present study was the first to investigate the association between resilience and the neurophysiological features of IGD patients using a resting−state EEG approach.

In conclusion, the present results demonstrated that IGD patients with low resilience had lower alpha absolute power and increased alpha coherence, especially in the right hemisphere. Furthermore, indirect effects of IGD on alpha coherence in the right hemisphere through depressive symptoms and stress level were significant only in IGD patients with the lower degree of resilience. Resilience is a crucial protective trait against the development and maintenance of IGD. Thus, understanding the neurophysiological mechanisms underlying resilience may help to establish effective strategies for treating IGD patients and prevent the occurrence of IGD.

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국문초록

인터넷 게임 장애는 지속적이고 과도한 인터넷 게임 사용으로 인한 심리적 부적응 상태를 일컫는다. 기존의 많은 연구는 인터넷 게임 장애의 위험요인과 보호요인에 대해 다루고 있는데, 그 중에서 회복탄력성은 최근 인터넷 게임 장애의 중요한 보호요인의 하나로 주목을 받고 있다. 회복탄력성은 생리적 혹은 심리적 위험 요인에 직면했을 때, 어려움을 극복하고 환경에 성공적으로 적응하고자 하는 개인적 특성을 지칭한다. 즉, 탄력적인 개인일수록 스트레스에 덜 민감하게 반응하며, 일시적으로 부적응 상태가 되더라도 다시 이전의 적응 수준으로 빠르게 돌아갈 수 있게 된다. 최근 회복탄력성을 심리학적뿐만 아니라 신경생리학적 관점과 함께 통합적으로 이해하려는 연구가 늘고 있다. 그럼에도 불구하고 인터넷 게임 장애와 회복탄력성의 메커니즘은 심리학적 접근에 한정되어 있으며, 신경생리학적 설명은 비교적 알려진 바가 많지 않다. 따라서 본 연구에서는 회복탄력성과 인터넷 게임 장애의 관계를 휴지기 뇌파를 이용해 신경생리학적으로 탐색하는 것을 목적으로 한다.

총 71명의 남성 피험자 (인터넷 게임 장애군 35명, 정상대조군 36명)가 본 연구에 참가하였다. 회복탄력성과 관련된 뇌파 특징을 탐색하기 위해 인터넷 게임 장애군을 Connor-Davidson 회복탄력성 척도(CD-RISC)의 50 백분위수에 따라 두 집단 (저회복탄력성 인터넷 게임 장애군 16명, 고회복탄력성 인터넷 게임 장애군 19명)으로 나누었다. 첫 번째로 촬영된 뇌파 자료는 스펙트럼 분석을 통해 알파파, 베타파, 감마파에서 절대역을 산출하였고, 회복탄력성 집단에 따른 절대역의 두

뇌 영역별(전두엽, 두정엽, 후두엽), 반구별 (좌반구, 우반구) 영향을 일반화 추정 방정식으로 분석하였다. 다음으로 각 스펙트럼 별 (알파파, 베타파, 감마파) 코히어런스 (기능적 연결성)를 산출하여 회복탄력성 집단에 따라 반구 내, 반구 간 코히어런스가 어떻게 달라지는지 비교하였다. 마지막으로 인터넷 게임장애가 임상 변인 (우울 증상, 스트레스 수준)을 통해 뇌파 특성에 미치는 매개효과를 확인하고 이를 회복탄력성이 어떻게 조절하는지 조절된 매개효과를 확인하였다.

본 연구의 결과는 다음과 같다. 회복탄력성이 낮은 인터넷 게임 장애군은 정상대조군보다 감소한 알파 절대역을 보였다. 또한, 회복탄력성이 높은 인터넷 게임 장애군과 정상대조군에 비해 우반구의 알파 코히어런스가 증가했음을 알 수 있었다. 특히, 우반구의 알파 코히어런스는 회복탄력성 (CD−RISC 점수)과 부적 상관관계, 임상 변인과는 정적 상관관계가 있었다. 이에 따른 매개효과 및 조절된 매개 효과를 분석한 결과, 우울 증상과 스트레스 수준은 인터넷 게임 장애와 우반구 알파 코히어런스의 관계를 완전 매개하였고, 회복탄력성은 이 매개효과를 유의미하게 조절하였다. 즉, 인터넷 게임 장애 환자의 회복탄력성이 낮을수록 정상대조군보다 심각한 우울 증상과 높은 스트레스 수준을 보였고, 이는 증가된 우반구 알파 코히어런스에 영향을 주는 조건부 간접효과가 나타났다. 반면 회복탄력성이 높은 인터넷 게임 장애군에서는 이 효과가 유의미하지 않았다.

본 연구는 인터넷 게임 장애와 회복탄력성이 신경생리학적으로 상관관계가 있음을 밝혔다. 본 연구의 결과를 통해서 인터넷 게임 장애의 보호요인인 회복탄력성을 심리학적 관점뿐만 아니라 신경생리학적 관점과 함께 통합적으로 살펴볼 필요가 있음을 제안한다. 이러한 통합적 접근을 통해 인터넷 게임 장애를 보다 효과적으로 예방하고 치료할 수 있기를 기대한다.