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Impact of attention-deficit/hyperactivity disorder comorbidity on longitudinal course in Internet gaming disorder: a 3-year clinical cohort study

Jung Lee,[1] Sujin Bae,[2] Bung Nyun Kim,[3] and Doug Hyun Han[2]

[1]Integrative Care Hub, Children's Hospital, Seoul National University Hospital, Seoul, Korea; [2]Department of Psychiatry, Chung Ang University Hospital, Seoul, Korea; [3]Division of Child and Adolescent Psychiatry, Department of Psychiatry, Seoul National University College of Medicine, Seoul, Korea

Background: Although attention-deficit/hyperactivity disorder (ADHD) symptoms were identified as a key risk factor for Internet gaming disorder (IGD), the effect of ADHD comorbidity on longitudinal course of IGD in the clinical population remains to be further examined. This study aimed to investigate whether ADHD comorbidity in IGD patients affects the recovery, recurrence rates, and trajectories of IGD symptoms, and examine the relationship between the changes in IGD and ADHD symptoms. **Methods:** The study included 128 IGD patients without any psychiatric comorbidities (pure-IGD group) and 127 IGD patients with comorbid ADHD (ADHD-IGD group) aged 11 to 42 years. IGD and ADHD were diagnosed according to DSM-5 criteria at enrollment. Participants were offered 8-week treatment with additional care provided as needed and followed up over a 3-year period. IGD diagnosis was reassessed annually and used as a dichotomous outcome. The severity of IGD and ADHD symptoms was measured using the Young Internet Addiction Scale and the Korean ADHD rating scale, respectively, at baseline and each annual follow-up. **Results:** The recovery rates of IGD by Year 3 were 60% and 93% in ADHD-IGD and in pure-IGD groups, respectively. The ADHD-IGD group showed lower rates of recovery, higher odds of recurrence within 1 year, and higher severity of IGD symptoms over time than the pure-IGD group. Family environment was also associated with the trajectories of IGD symptoms. The changes in ADHD symptoms were significantly associated with the changes in IGD symptoms. **Conclusions:** This study found that ADHD comorbidity in IGD patients was associated with poor clinical course of IGD and that the changes in ADHD symptoms were associated with the changes in IGD symptoms over time. Our findings suggest that evaluation and treatment of ADHD symptoms and family environment in IGD patients may be important in improving the prognosis of IGD. **Keywords:** Internet gaming disorder; clinical course; ADHD comorbidity.

Introduction

Recently, computer game playing has become an indispensable leisure activity for youth. Computer gaming is part of a normal, healthy life and is shown to have a number of beneficial effects on mental well-being through providing positive emotions, opportunities to develop and maintain positive relationships, and a sense of achievement (Anderson, Steen, & Stavropoulos, 2017; Jones, Scholes, Johnson, Katsikitis, & Carras, 2014). However, for some individuals with various internal and external risk factors, computer gaming may also become pathological when it is associated with significant impairment in the individual's social, occupational, school, and psychological functioning (Ferguson, Coulson, & Barnett, 2011; Kuss & Griffiths, 2012; Lehenbauer-Baum & Fohringer, 2015; Paulus, Ohmann, von Gontard, & Popow, 2018).

The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), conceptualizes 'Internet gaming disorder (IGD)' under 'Conditions for further study', suggesting that this proposal is not yet intended for clinical use but that research on this topic be encouraged (American Psychiatric Association, 2013). Recently, 'gaming disorder' was defined as a distinct nosological entity under the addictive disorders section of the 11th Revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-11; World Health Organization, 2018). However, the concept of IGD is still debatable because clinical data on symptoms of its 'true' addiction are lacking, negative consequences may be overemphasized, and Internet gaming could be related to inefficient strategies of dealing with life problems or other underlying mental health problems (Aarseth et al., 2017).

There is only a handful of longitudinal evidence exploring antecedents and consequences of IGD symptoms (Rothmund, Klimmt, & Gollwitzer, 2018; Scharkow, Festl, & Quandt, 2014; Wartberg, Kriston, Zieglmeier, Lincoln, & Kammerl, 2018; Weinstein, Przybylski, & Murayama, 2017). Moreover, different measurements, cutoff criteria of problematic gaming, and sample characteristics were used for previous studies, leading to inconsistent results on the prevalence, behavioral stability, and clinical outcomes of IGD (Darvesh et al., 2020; Paulus et al., 2018; Przybylski, 2016; Przybylski, Weinstein, & Murayama, 2017; Wartberg et al., 2018). Furthermore,

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since previous studies were mostly conducted in healthy populations using only self-report questionnaires, information on the characteristics of actual patients with IGD diagnosed by professionals in clinical settings is surprisingly scarce (van Rooij, Schoenmakers, & van de Mheen, 2017).

Attention-deficit/hyperactivity disorder (ADHD) has been regarded as one of the most prevalent comorbidities of IGD besides depressive and anxiety disorders (Anderson et al., 2017; Carli et al., 2013; Gonzalez-Bueso et al., 2018b; Yen et al., 2017). Recent cross-sectional studies with community samples found that ADHD symptoms were closely associated with IGD symptoms (Aggarwal, Saluja, Gambhir, Gupta, & Satia, 2020; Evren, Evren, Dalbudak, Topcu, & Kutlu, 2019a, 2019b; Jung et al., 2020; Stavropoulos et al., 2019). Several community-based longitudinal studies indicated that ADHD was a predictor of the development of IGD (Ferguson & Ceranoglu, 2014; Peeters, Koning, & van den Eijnden, 2018; Wartberg et al., 2018). Yet, relatively few studies have examined these issues on a clinical level. Han, Yoo, Renshaw, and Petry (2018) in a longitudinal clinical cohort study investigated 755 IGD patients over a 5-year period and found that the comorbid condition of ADHD was one of the key predictable factors for long-term recovery of IGD. However, DSM-5 criteria of IGD and scheduled follow-up assessments were not implemented in this study. Therefore, we performed this study with a longitudinal design in a clinical population to address these limitations of previous studies and shed more light on the clinical course of IGD and the impact of ADHD comorbidity on the course.

This study aimed to investigate whether ADHD comorbidity in IGD patients affects the recovery, recurrence rates of IGD, and the trajectories of IGD symptoms. In addition, the relationship between the longitudinal changes in IGD and ADHD symptoms in IGD patients was examined. Based on the literature, we established the following hypotheses: (a) The ADHD-IGD group would have lower recovery rates and higher recurrence rates than the pure-IGD group; (b) the IGD symptoms of the ADHD-IGD group would decrease less than in the pure-IGD group over time; and (c) the changes in IGD symptoms would relate to the changes in ADHD symptoms over time.

Methods

Participants

This study is part of a cohort named 'problematic Internet gaming group', with the broad goal of exploring clinical and neural outcomes related to IGD and comorbid psychiatric disorders. Participants were recruited from the outpatient psychiatric clinics of Chung-Ang University Hospital. IGD was diagnosed according to DSM-5 criteria using a Structured Clinical Interview for Internet Gaming Disorder (SCI-IGD; Koo, Han, Park, & Kwon, 2017). Psychiatric comorbidities were evaluated using the Kiddie-Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version (K-SADS-PL) (Kaufman et al., 1997, 2016; Kim et al., 2004) and Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-IV; First, 1997; Hahn et al., 2000). The diagnosis of ADHD in adults was made by psychiatrists according to DSM-5 after a thorough interview with patients and informants. Exclusion criteria for the cohort included intelligence quotient (IQ) lower than 70, a history of psychotic disorders, current psychotropic medication usage, and neurological or medical diseases. A total of 407 participants with IGD were enrolled from 2013 to 2015. Among them, this study included 128 individuals who had no other psychiatric disorder (pure-IGD group: 22.3 ± 6.5 years; ages: 12–42) and 127 individuals who had comorbid ADHD (ADHD-IGD group: 20.1 ± 5.7 years; ages: 11–34).

Procedures

Ethical Considerations: The Institutional Review Board for Human Subjects at Chung-Ang University Hospital approved the study, while written informed consent was obtained from all participants and parents of children and adolescents.

All participants were offered 8-week course treatment involving cognitive-behavioral therapy and medications for symptoms of depressive mood, poor attention, and impulse and behavior control (Kim, Han, Lee, & Renshaw, 2012). At the end of the treatment, patients who had not fully recovered from IGD were offered additional care including medications for comorbid disorders and supportive psychotherapy. These additional treatments were provided until recovery from IGD or patient-initiated termination of care. Regardless of completion of the 8-week treatment and additional treatments, participants were followed up at Years 1, 2, and 3.

Behavioral ratings and assessments

IGD, ADHD symptoms, and other clinical characteristics were assessed at baseline and each annual follow-up. IGD diagnosis was reassessed annually and used as a dichotomous outcome (IGD vs. non-IGD). The severity of IGD symptoms was measured using the Young Internet Addiction Scale (YIAS; Yoo et al., 2004; Young, 1996), and the scores were used as a continuous outcome. Severity of ADHD symptoms was measured with a parent-rated Korean ADHD rating scale (ADHD-RS; DuPaul, Power, Anastopoulos, & Reid, 1998; So, Noh, Kim, Ko, & Koh, 2002) for youths or with an informant-rated ADHD-RS for adults. Depression and anxiety symptoms were assessed using Beck's Depression Inventory (BDI) (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961; Lee et al., 1995) and Beck's Anxiety Inventory (BAI) (Beck, Epstein, Brown, & Steer, 1988; Kwon, 1997), respectively. With respect to social interaction factors, social distress and family environment were evaluated using Social Avoidance and Distress Scale (SADS; Lee & Choi, 1997; Watson & Friend, 1969) and Family Environment Scale (FES; Moos, 1994), respectively. The values of coefficient alpha of the scales were as follows: 0.948 for YIAS, 0.902 for parent-rated ADHD-RS, 0.958 for informant-rated ADHD-RS, 0.953 for BDI, 0.914 for BAI, 0.881 for SADS, and 0.918 for FES.

Statistical analysis

Probabilities of recovery and recurrence (for those who obtained recovery) in IGD were compared between the pure-IGD group and the ADHD-IGD group using survival analysis for interval-censored data (Bukh, Andersen, & Kessing, 2016; Fay & Shaw, 2010). (a) Recovery: Since the time to recovery was known only up to a certain level, the time to recovery was 'interval-censored' between the 1-year intervals when patient diagnosis changed from IGD to non-IGD. Participants who did not achieve recovery at any time during the follow-up period had their times to recovery right-censored at last assessments.

(b) Recurrence: 138 participants who achieved recovery were followed up from the time of recovery of IGD. The time to recurrence was interval-censored between the 1-year intervals when patient diagnosis changed from non-IGD to IGD. Participants who did not have recurrence had their times to recurrence right-censored at last follow-up. To compare the survival distributions between groups, we used the nonparametric maximum-likelihood estimator (NPMLE) and weighted log-rank test (WLRT) derived from the linear transformation model for interval-censored data (Fay & Shaw, 2010). A semiparametric proportional hazards model for interval-censored data was used to assess the effects of ADHD comorbidities on the recovery of IGD after controlling for age-group (10–19, 20–29, and ≥30 years) at enrollment and dichotomous IQ (<100, ≥100). The proportionality assumption was tested using graphic techniques (Anderson-Bergman, 2017). Since there were no recurrences after recovery in the age-group 30 years or older, leading to a complete separation problem, we performed logistic regression with Firth's bias reduction method (Firth, 1993) to investigate the relationship between ADHD comorbidities and IGD recurrence within 1 year after recovery adjusting for age-group and IQ.

To examine the impact of ADHD comorbidity on the changes in IGD symptom severity (YIAS scores) over time after controlling for demographic and psychosocial confounders, we used mixed-effects linear regression. Time, the presence of ADHD comorbidity (pure-IGD vs ADHD-IGD), age-group at enrollment, IQ, time by ADHD comorbidity interactions, time by age-group interactions, and time-varying covariates were kept in the model as fixed effects, while intercept was set as a random effect. We included the following time-varying covariates: BDI, BAI, SADS, FES scores, and the use of psychiatric intervention (outpatient treatments and/or psychotropic medication) during the previous 1 year (yes/no) at baseline and each annual follow-up. There was no multicollinearity in this model, with the highest VIF at 2.0.

We implemented multivariate mixed-effects models (Baldwin, Imel, Braithwaite, & Atkins, 2014; Long, 2011; MacCallum, Kim, Malarkey, & Kiecolt-Glaser, 1997; Suvak, Walling, Iverson, Taft, & Resick, 2009) to examine whether the change in IGD symptom severity was related to the change in ADHD symptom severity over time. Multivariate mixed models involve computing two or more growth trajectories simultaneously in one model. Detailed information for the model specification was described in the Supporting Information section (Appendix S1). In such models, the variance–covariance matrix among fixed effects is estimated. This provides a basis for direct statistical comparisons among the change curves. Our primary interest was in examining the relationship between the random slopes from each growth trajectory to assess how person-specific rates of change in ADHD and IGD trajectories are related. The correlation coefficients between individual intercepts (r_I) and between individual slopes (r_S) of two outcomes were calculated from the variance/covariance matrix for the random effects with the following formula.

$$r_I = \frac{\sigma_{u_1 u_3}}{\sqrt{\sigma^2_{u_1}}\sqrt{\sigma^2_{u_3}}}$$

u_1: random intercepts for ADHD symptoms and u_3: random intercepts for IGD symptoms.

$$r_S = \frac{\sigma_{u_2 u_4}}{\sqrt{\sigma^2_{u_2}}\sqrt{\sigma^2_{u_4}}}$$

u_2: random slopes for IGD symptoms and u_4: random slopes for IGD symptoms.

All analyses were performed using R, version 3.5.0 (R Core Team, 2018). We used the R package interval (Fay & Shaw, 2010) to fit the NPMLE model and performed WLRT for survival analysis with interval-censored data. A semiparametric proportional hazards model was fitted using the R package icenReg (Anderson-Bergman, 2017). Logistic regression applying Firth's bias reduction method was conducted using the R package logistf (Heinze, Ploner, Dunkler, & Southworth, 2018). Mixed-effects linear regression and multivariate mixed-effects models were fitted using the R package lme4 (Bates, Sarkar, Bates, & Matrix, 2007).

Results

Sample description

The demographic and clinical characteristics at baseline of the pure-IGD and ADHD-IGD groups are presented in Table 1. Although there was a significant difference in mean age between the groups, the age-group distribution did not differ significantly between the groups. The groups did not differ in gender and IQ. There was a significant diagnosis effect on the ADHD-RS total scores. The ADHD-IGD group had significantly higher YIAS scores. The pure-IGD group had significantly higher BDI and BAI scores, although the scores were lower than cutoff scores indicating clinical depression and anxiety. There were no significant differences in SADS and FES scores. The 3-year assessment was completed by 62.7% (160/255) of participants. Follow-up rates at Years 1, 2, and 3 did not differ significantly between the two groups. Although the involvement with psychiatric intervention during the first and second year was not significantly different between groups, the ADHD-IGD group was more likely to receive psychiatric interventions than the pure-IGD group in the third year.

Recovery and recurrence of IGD between groups

Recovery: The ADHD-IGD group showed a lower probability of recovery than the pure-IGD group (Figure 1, $p < .001$). The recovery rates in the ADHD-IGD group were estimated 17%, 42%, and 60% by Years 1, 2, and 3, respectively. The recovery rates in the pure-IGD group were estimated 49%, 57%, and 93% by Years 1, 2, and 3, respectively. The ADHD-IGD group showed a significantly lower likelihood of recovery even after adjusting for age at baseline and IQ (hazard ratio, 0.26; 95% CI, 0.17-0.40; $p < .001$).

Recurrence: The ADHD-IGD group had a higher probability of subsequently having a recurrence over the follow-up period (Figure 2, $p = .006$). The recurrence rates over 2 years of ADHD-IGD and pure-IGD groups were estimated 0.24 and 0.04, respectively. The ADHD-IGD group had significantly higher odds of recurrence within 1 year than the pure-IGD group (odds ratio, 4.98; 95% CI, 1.19–29.37; $p = .03$).

Longitudinal changes in IGD symptoms between groups

Figure 3 shows the trajectories of IGD symptoms during a 3-year follow-up among participants in pure-

Table 1 Demographic and clinical characteristics at enrollment by ADHD comorbidity in a 3-year longitudinal follow-up study of individuals with IGD

	Pure-IGD (n = 128)	ADHD-IGD (n = 127)	Test	p Value
Age-group, No. (%)				
10-19 years	54 (42%)	70 (55%)	χ^2 = 4.37	.11
20–29 years	58 (45%)	46 (36%)		
≧30 years	16 (13%)	11 (9%)		
IQ, mean (*SD*)	101.2 (13.6)	98.4 (15.7)	t = 1.53	.13
IQ (≧100), No. (%)	60 (47%)	58 (46%)	χ^2 = 0.005	.95
Male, No. (%)	121 (95%)	125 (98%)	Fisher's	.17
YIAS, mean (*SD*)	58.6 (6.9)	66.6 (9.1)	t = −7.85	<.001
ADHD-RS, mean (*SD*)	9.8 (4.3)	27.8 (6.4)	t = −25.3	<.001
BDI, mean (*SD*)	11.1 (5.8)	8.9 (4.8)	t = 3.25	.001
BAI, mean (*SD*)	8.5 (7.6)	6.3 (4.3)	t = 2.83	.005
SADS, mean (*SD*)	74.4 (13.8)	77.2 (15.6)	t = −1.49	.14
FES, mean (*SD*)	10.7 (3.0)	10.1 (3.1)	t = 1.63	.10
Follow-up rate, No. (%)				
Year 1	106 (84%)	116 (91%)	χ^2 = 3.39	.07
Year 2	89 (70%)	101 (80%)	χ^2 = 2.85	.09
Year 3	73 (57%)	87 (69%)	χ^2 = 3.12	.08
Use of psychiatric interventions[a] during the previous year (Yes), No. (%)				
Year 1	89 (84%)	85 (73%)	χ^2 = 3.13	.08
Year 2	53 (61%)	76 (75%)	χ^2 = 3.82	.051
Year 3	21 (29%)	51 (59%)	χ^2 = 13.16	<.001

Abbreviations: ADHD-RS = ADHD rating scale; BAI = Beck's Anxiety Inventory; BDI = Beck's Depression Inventory; FES = Family Environment Scale; SADS = Social Avoidance and Distress Scale; YIAS = Young Internet Addiction Scale.
[a]Psychiatric intervention included cognitive-behavioral therapy, supportive psychotherapy, and medications for symptoms of depressive mood, poor attention, and impulse and behavioral control.

IGD and ADHD-IGD groups. Linear mixed modeling (Table 2) found that IGD symptoms significantly improved over time for both groups (0.27 *SD* decrease in YIAS per year; 95% CI, −0.34 to −0.21); the ADHD-IGD group showed consistently higher severity of IGD symptoms than the pure-IGD group during follow-up periods. ADHD comorbidity (pure-IGD vs. ADHD-IGD) by time interaction was not statistically significant. Age-group 20–29 years showed higher severity of IGD symptoms than the other age-groups. Participants of age 30 or older at enrollment showed greater improvement in IGD symptoms than those in other age-groups (p < .001 for group–time interaction). Higher anxiety symptoms were positively associated with IGD symptoms (β = 0.09; 95% CI, 0.04 to 0.15), and better family environment was negatively associated with IGD symptoms over time (β = −0.33; 95% CI, −0.38 to −0.27). Participants who received psychiatric intervention during the previous year showed significantly lower severity of IGD symptoms (β = −0.22; 95% CI, −0.30 to −0.13). By comparing the standardized coefficients, family environment scores had the highest impact on IGD symptoms among the clinical covariates.

Relationship between changes in IGD and ADHD symptoms

Multivariate mixed-effects model indicated strong positive relationships between the person-specific baseline values of YIAS and ADHD-RS (r_I = 0.75, p < .001) and the person-specific rates of change for YIAS and ADHD-RS (r_S = 0.75, p < .001). This suggests that ADHD symptoms were positively associated with IGD symptoms at baseline and that changes in ADHD symptoms were highly associated with changes in the IGD symptoms.

Discussion

To the best of our knowledge, this is the first longitudinal study to investigate the effect of ADHD comorbidity on clinical course of IGD. The data suggest that IGD patients with comorbid ADHD had lower recovery rates and higher recurrence rates than IGD patients without comorbidity. Although the IGD symptoms improved over time regardless of comorbid ADHD, patients with comorbid ADHD showed higher severity of IGD symptoms over time. Additionally, decreases in ADHD symptoms were related to decreases in IGD symptoms over time.

As expected, our analyses showed that ADHD comorbidity was associated with a more chronic course of IGD with lower rates of recovery and higher rates of recurrence. Our results are consistent with a recent community-based cohort study which followed young men at ages 20 and 25, showing that gaming disorder was more likely to be persistent in the participants with ADHD and gaming disorder than those with only gaming disorder (Marmet, Studer, Grazioli, & Gmel, 2018). These consistent findings from clinical and community samples suggest that ADHD is a predictor not only for the occurrence but also for a poor course of IGD. Studies have suggested that the link between ADHD and IGD could be potentially explained by the characteristics

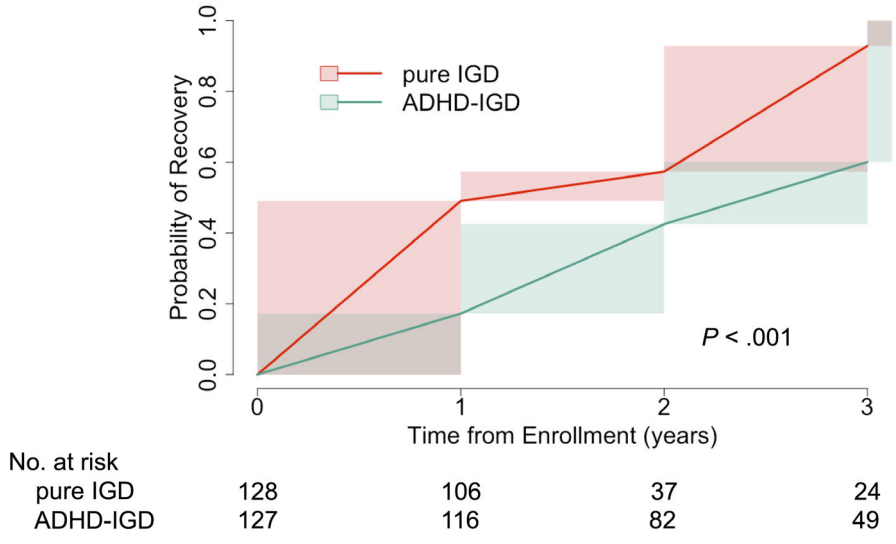

Figure 1 3-year cumulative probability of IGD recovery among participants with IGD only (pure-IGD) and those with IGD and ADHD (ADHD-IGD). The ADHD-IGD group showed a lower probability of recovery than the pure-IGD group (<.001). The recovery rates in the ADHD-IGD group were estimated 17%, 42%, and 60% by Years 1, 2, and 3, respectively. The recovery rates in the pure-IGD group were estimated 49%, 57%, and 93% by Years 1, 2, and 3, respectively

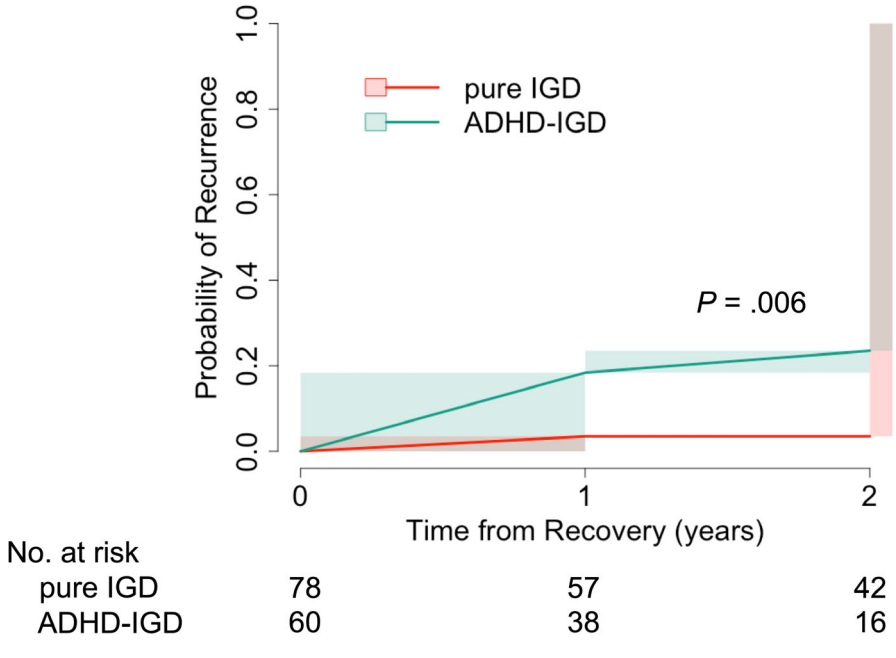

Figure 2 Cumulative probability of IGD recurrence among participants with IGD only (pure-IGD) and those with IGD and ADHD (ADHD-IGD). The ADHD-IGD group had a higher probability of subsequently having a recurrence over the follow-up period (p = .006). The recurrence rates over 2 years in the ADHD-IGD and pure-IGD groups were estimated 0.24 and 0.04, respectively

of Internet gaming providing a continuous stream of stimulation and immediate reward, which, in turn, is highly appreciated by individuals with ADHD, who tend to be easily bored and aversive toward delayed gratifications (Castellanos & Tannock, 2002; Diamond, 2005; Yen, Yen, Chen, Tang, & Ko, 2009). Other studies hypothesized that this link might be explained by impaired working memory function in ADHD (Castellanos & Tannock, 2002). Referring to this, the features of computer games providing on-hand assistance through display of mission help ADHD patients to overcome their working memory impairment and achieve high performance in games. In addition, Koepp and colleagues reported that video gaming leads to a striatal dopamine release, possibly resulting in better concentration and performance, which might be perceived as a relief by individuals with ADHD whose cognitive skills are impaired in real life (Han et al., 2009; Koepp et al., 1998).

It is also important to note that family environment was one of the key influential factors on IGD symptoms over time. The importance of family environment has been emphasized in other studies on

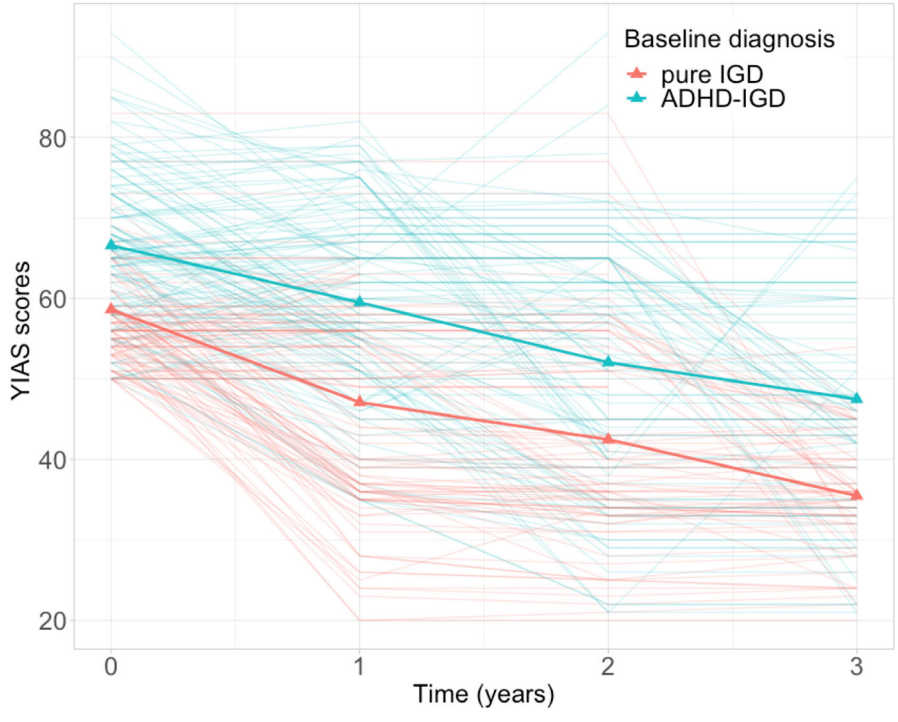

Figure 3 Trajectories of IGD symptoms measured by YIAS during a 3-year follow-up. Thick lines represent observed mean curves of YIAS scores, and thin lines represent individual curves of YIAS scores in the pure-IGD and ADHD-IGD groups. Linear mixed modeling found that IGD symptoms significantly improved over time for both groups (0.27 *SD* decrease in YIAS per year; 95% CI, −0.34 to −0.21) without group by time interaction (p = .51). The ADHD-IGD group showed consistently higher severity of IGD symptoms than the pure-IGD group during follow-up periods

Table 2 Correlates of IGD symptom severity (YIAS scores) over time in patients with IGD: mixed effects linear regression analysis

	β (95% CI)	*p* Value
Time	−0.27 (−0.34 to −0.21)	<.001
ADHD comorbidity (reference: pure-IGD)		
ADHD-IGD	0.57 (0.40 to 0.73)	<.001
Time by ADHD-IGD	−0.02 (−0.09 to 0.05)	.51
Age-group at baseline (reference: 10-19 years)		
20–29 years	0.23 (0.06 to 0.41)	.007
≧30 years	0.01 (−0.26 to 0.27)	.95
Time by 20–29 years	0.02 (−0.05 to 0.09)	.54
Time by ≧30 years	−0.26 (−0.37 to −0.15)	<.001
Clinical covariates		
BDI	0.02 (−0.04 to 0.07)	.52
BAI	0.09 (0.04 to 0.15)	<.001
SADS	0.06 (0.001 to 0.12)	.047
FES	−0.33 (−0.38 to −0.27)	<.001
Use of psychiatric interventions[a]: Yes	−0.22 (−0.30 to −0.13)	<.001

Abbreviations: ADHD-RS = ADHD rating scale; BAI = Beck's Anxiety Inventory; BDI = Beck's Depression Inventory; FES = Family Environment Scale; SADS = Social Avoidance and Distress Scale; YIAS = Young Internet Addiction Scale.
[a]Psychiatric intervention included cognitive-behavioral therapy, supportive psychotherapy, and medications for symptoms of depressive mood, poor attention, and impulse and behavioral control.

pathologic gaming or problematic Internet use. Poor family functioning was associated with IGD in a cross-sectional study with a representative sample of German adolescents (Wartberg, Kriston, & Thomasius, 2020) and predicted the emergence of the problematic Internet use in prospective studies with a sample of Taiwanese adolescents (Ko, Yen, Yen, Lin, & Yang, 2007). A prospective study with a sample of Korean adolescents showed that family environmental factors influence the adolescents' academic stress and eventually the degree of pathological gaming (Jeong, Ferguson, & Lee, 2019). Inversely, better family support predicted a higher remission rate of Internet addiction in a prospective study with a sample of Chinese adolescents (Lau, Wu, Gross, Cheng, & Lau, 2017). Therefore, our findings with clinical patients with IGD may be in line with the previous studies with community samples, suggesting the family environments and functioning intertwine with the trajectories of IGD symptoms.

The longitudinal associations between ADHD and IGD symptoms which have been reported from several community-based cohort studies were also identified in our clinical cohort study. Although cross-sectional and longitudinal associations between ADHD and IGD have clear evidence, caution is needed in interpreting the direction of causality because previous studies have reported inconsistent results on this issue. Ferguson and Ceranoglu (2014) showed that attentional problems led to pathological gaming 1 year later, but not the inverse in adolescents using path analysis. This unidirectional longitudinal association was also revealed in a cross-

lagged panel design study using larger community sample of adolescents (Wartberg et al., 2018). However, a more recent longitudinal study with young adults found a bidirectional association between ADHD symptoms (especially, inattentive symptoms) and gaming disorder symptoms (Marmet et al., 2018). Further researches with larger clinical sample size are certainly required regarding direction of the causality between ADHD and IGD symptoms.

From a clinical perspective, our results indicate the importance of evaluation and treatment for ADHD symptoms in treatment-seeking patients with IGD. As a treatment strategy, previous studies with patients with ADHD showed that pharmacotherapy for ADHD could reduce the severity of IGD symptoms (Chang, Chang, Cheng, & Tzang, 2020; Park, Lee, Sohn, & Han, 2016). We also found that the use of psychiatric intervention including medications for comorbid ADHD was associated with the reduction in IGD symptoms. Therefore, pharmacological and also psychotherapeutic interventions aiming for reduction in poor attention, and impulse and behavioral control might be a crucial part of intervention for IGD. In addition, due to the significant impact of family environment on the clinical course of IGD, treatment for IGD should include enhancing the family environment and functioning of patients with IGD. There has been growing evidence that specialized psychological programs for IGD utilizing family intervention may be effective for patients with IGD (Gonzalez-Bueso et al., 2018a; Han, Seo, Hwang, Kim, & Han, 2020; Torres-Rodriguez, Griffiths, Carbonell, & Oberst, 2018).

Limitations

There were several limitations to this study. First, in patients in the pure-IGD group, almost half of the participants dropped out at Year 3, and the follow-up rates were significantly lower than those in the ADHD-IGD group. Although the statistical methods we used have been known to efficiently deal with data sets comprising missing outcome data (Pinheiro & Bates, 2000), our results may be influenced by factors that impacted dropout from the follow-up. Second, annual follow-up schedule might have impaired the exact dating of the time of recovery and recurrence. However, since IGD in DSM-5 refers to a time frame of 12 months in which symptoms have occurred (American Psychiatric Association, 2013), a one-year interval between assessments could be acceptable to investigate clinical course of IGD. Third, we should be cautious to generalize the findings of this study, using IGD criteria of DSM-5, to gaming disorder defined by ICD-11. Gaming disorder criteria in ICD-11 were reported to be stricter, to reflect more severe conditions compared with the IGD criteria in DSM-5 (Jo et al., 2019). Finally, this study was a naturalistic follow-up of patients who began treatment over a 3-year period. Therefore, naturally occurring changes in treatment, gaming, and the society may also have impacted the results.

Conclusions

In summary, the results of this study indicate that ADHD comorbidity in IGD patients is associated with poor longitudinal course of IGD, including lower recovery, higher recurrence, and higher symptom severity over time relative to patients without any comorbidities. The severity and the longitudinal changes in ADHD symptoms were associated with those of IGD symptoms over time in IGD patients with. From a clinical perspective, evaluation and treatment of ADHD symptoms and family environment in IGD patients are important to improve the prognosis of IGD. Further longitudinal studies are warranted to evaluate the pathologic mechanism of the relationship between ADHD and IGD.

Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article:

Appendix S1. Detailed information for the multivariate mixed effects models.

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Correspondence

Bung Nyun Kim, Division of Child and Adolescent Psychiatry, Department of Psychiatry, Seoul National University College of Medicine, 103 Daehak-ro, Jongno-gu, Seoul 03080, Korea; Email: kbn1@snu.ac.kr

Doug Hyun Han, Department of Psychiatry, Chung Ang University Hospital, 102 Heukseok-ro, Dongjak-gu, Seoul 06973, Korea, Email: hduk70@gmail.com

Key points

- ADHD symptoms were identified as a key risk factor for IGD, but the effect of ADHD comorbidity on longitudinal course of IGD in the clinical population is yet to be examined.
- In this clinical cohort study, IGD patients with ADHD showed lower rates of recovery, higher rates of recurrence, and higher severity of IGD symptoms during 3-year follow-up periods compared to IGD patients without any psychiatric comorbidities.
- A positive relationship was found between the changes in ADHD and IGD symptoms over time.
- These findings suggest that the evaluation and treatment of ADHD symptoms in IGD patients may be important in improving the prognosis of IGD.

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