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FULL-LENGTH REPORT

Low self-control and aggression exert serial mediation between inattention/hyperactivity problems and severity of internet gaming disorder features longitudinally among adolescents

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ABSTRACT

Objectives: We examined serial mediating roles of low self-control and aggression in explaining relationships between levels of inattention and hyperactivity problems (IHPs) and severity of Internet gaming disorder (IGD) features when exposed to online games among adolescents without Attention deficit hyperactivity disorder (ADHD) stratified by gender using three-wave longitudinal study. *Method:* The sample comprised a total of 1,732 family dyads from a study that was conducted among seventh graders without diagnoses of ADHD at baseline. Levels of IHPs were assessed by the parent reported Korean version of the ADHD rating scale at baseline (wave1). Severity of IGD features was assessed by the Internet Game Use-Elicited Symptom Screen (IGUESS) at wave3. Both levels of self-control (wave1) and aggression (wave2) were assessed by self-report. The mediating role of low self-control and aggression in the relationships between level of IHPs and severity of IGD were evaluated using serial mediation analysis separately for each gender. *Results:* Levels of IHPs were related directly to severity of IGD features in both genders. The indirect effects via low self-control were also significant in both genders, however, the indirect effects via aggression was significant only in women. The serial mediation effect via low self-control and aggression between levels of IHPs and IGD features was significant in both genders (men, coefficient:0.009, 95%CI 0.005–0.019; women, coefficient:0.010, 95%CI:0.005–0.026). *Conclusion:* We revealed a possible mechanism underlying a serial mediation chain from low self-control to aggression explaining the effects of IHPs on severity of IGD features. However, this conclusion should be taken with a caution, because the effect sizes were very low.

KEYWORDS

internet gaming disorder, inattention hyperactivity problem, self-control, aggression, serial mediation, adolescent, cohort

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INTRODUCTION

Although playing online games may provide beneficial and positive effects (Granic, Lobel, & Engels, 2014), excessive or addictive gaming is associated with aggression, maladaptive coping strategies, decreased academic achievement and performance. Individuals with gaming problems may sacrifice hobbies, sleep, and work (Ferguson, San Miguel, Garza, & Jerabeck, 2012; Kuss & Griffiths, 2012; Lam, 2014). Internet gaming disorder (IGD) was introduced by the American Psychiatric Association as a possible condition requiring further investigation (American Psychiatric Association, 2013), and gaming disorder has been officially classified as a "disorder due to addictive behaviors" by the World Health Organization (2018).

Attention deficit hyperactivity disorder (ADHD) is a common neurodevelopmental disorder of childhood that often persists into adulthood (Kidd, 2000). Individuals with ADHD show imbalances in neurobiological processes such as behavioral inhibition, self-regulation, and self-control, as well as altered reinforcement sensitivity (Hauser et al., 2014; Sebastian et al., 2014). The presence of ADHD symptoms increases the likelihood of exhibiting IGD symptoms (Gonzalez-Bueso et al., 2018; Pearcy, McEvoy, & Roberts, 2017; Yen, Chou, Liu, Yang, & Hu, 2014). Individuals with greater inattention and hyperactivity symptomatology have reported greater IGD symptom severity (Mathews, Morrell, & Molle, 2019). However, little is known about the mechanism underlying these relationships.

Low self-control may be defined by immediate and unplanned responses toward external stimuli (Potenza & de Wit, 2010). A longitudinal study suggested that low self-control represented a risk factor for becoming gaming problems among children and adolescents (Gentile et al., 2011). Lee et al. (2017) suggested that low self-control could be a marker of vulnerability to internet addiction because it is associated with the severity of internet addiction (Lee, Lee, & Choo, 2017). Impaired control has been posited as a main element in IGD and other addictive behaviors (Brand et al., 2019; Dong & Potenza, 2014). We hypothesized that low self-control contributes importantly to the occurrence and severity of gaming disorder in adolescents.

Aggression has been suggested as a vulnerability factor underlying problematic video-gaming, together with impulsivity and sensation-seeking (Lee et al., 2017). Aggressive behaviors have been linked to problematic video-gaming cross-sectionally (Zhai et al., 2019), and aggression may constitute a risk factor for IGD in adolescents (Gonzalez-Bueso et al., 2018; Paulus, Ohmann, von Gontard, & Popow, 2018), particularly as longitudinal data suggests that problematic video-gaming exerts a cross-lagged effect on physical aggression among adolescents (Lemmens, Valkenburg, & Peter, 2011).

Low self-control has longitudinal associations with aggressive and risk-taking behaviors (Pratt, Turanovic, Fox, & Wright, 2014; Reisig & Pratt, 2011). According to the Gottfredson and Hirschi (1990) General Theory of Crime, poor self-control is the source of aggressive and criminal behaviors (Gottfredson & Hirschi, 1990). Many studies have demonstrated robust associations between poor self-control and aggressive behavior or externalizing outcomes (Kühn et al., 2014; Rosen et al., 2014; Van Lange, Rinderu, & Bushman, 2017). Research across developmental periods has supported the notion that individuals who have self-regulation difficulties are more likely to show increased aggression and rule-breaking behaviors, including involvement in juvenile delinquency and later adult offending (Casey & Caudle, 2013; Glenn & Raine, 2014). Therefore, we examined serial mediating roles of low self-control and aggression in the relationships between level of IHPs and severity of IGD features using three wave longitudinal follow-up data.

Adolescence is a critical period of brain development and behavioral maturation, and adolescents are vulnerable to addictive behaviors (Casey & Caudle, 2013). Adolescents with greater disparities between frontal and limbic systems are more vulnerable to addictive disorders (Hammond, Mayes, & Potenza, 2014). Frontostriatal mismatch in neurodevelopment may contribute to increased impulsivity in children and adolescents (Lee et al., 2017). Higher levels of testosterone are released during the juvenile period than in other developmental stages, stimulating aggression and anger (Berenbaum, Beltz, & Corley, 2015; Blakemore, Burnett, & Dahl, 2010). Given the importance of emotional development, it is critical to understand whether it is susceptible to gender differences. We hypothesized that the levels of IHPs would directly and indirectly influence the severity of IGD features through mediators of low self-control and aggression among adolescents. In addition, we investigated gender difference in mediating role of low self-control and aggression in the relationship between the levels of IHPs and the severity of IGD features longitudinally.

MATERIALS AND METHODS

Study sample

The sample comprised a total of 1,732 family dyads (seventh grade adolescents and a parent or related caregiver each) derived from the iCURE study, which has been described in detail elsewhere (Jeong et al., 2017). A total of 2,319 third, fourth, and seventh grade students were enrolled in the iCURE study at baseline (wave 1). The follow-up assessments were completed at 12 months (wave 2) and 24 months (wave 3) after the baseline assessment. We included seventh grade students (n = 1,920) in the present study at baseline. Among them, we excluded those who did not complete follow-up assessment at wave 2 (n = 80) and wave 3 (n = 72), those who were diagnosed with ADHD by the Diagnostic Interview Schedule for Children, Version 4 (DISC-IV) (n = 30), and those who did not complete IHP assessments at wave 1 (n = 6). Individuals with ADHD were excluded given the focus of the present study on individuals without formal ADHD.

Measurements

Procedure. Adolescent data were collected at their schools during school hours at both baseline and follow-up assessments. All participants completed questionnaires using a self-administered web-based survey with a supervising research assistant available to answer questions. One of each adolescent's parents or primary caregivers completed self-administered questionnaires at the participant's home or in a private space in their child's school based on the participant's preferences at baseline.

Inattention and hyperactivity problems. IHPs were assessed according to the parent-report version of the Korean version of the ADHD rating scale (K-ARS) which was originally developed by Dupaul (1991). The K-ARS is an 18-item questionnaire based on DSM-IV ADHD. The K-ARS consists of two subscales, inattention and hyperactivity-impulsivity, each containing nine items. Parents were required to rate the frequency of each of the ADHD symptoms occurring over the past 12 months on a four-point Likert scale with 1 for never or rarely, 2 for sometimes, 3 for often, and 4 for very often. The sum of all 18 item scores results in a total score. The reliability and validity of the home version of the K-ARS was verified in a sample of Korean children and adolescents (So, Noh, Kim, Ko, & Koh, 2002). The internal consistency of the K-ARS for the present sample was 0.89. Higher scores indicated more severe ADHD symptoms.

Low self-control. Self-control was assessed using a self-reported self-control rating scale originally developed by Gottfredson and Hirschi (Gottfredson & Hirschi, 1990). The scale contains 20 items that are divided into two self-control domains relating to immediate and delayed satisfaction-seeking tendencies. We used 10 items to assess immediate satisfaction-seeking tendency in this analysis, reflecting low self-control. Each item is rated on a 4-point scale: (4) strongly agree, (3) agree somewhat, (2) disagree somewhat, and (1) strongly disagree. Higher scores indicate lower self-control [24]. Cronbach's alpha was 0.86 in this study.

Level of aggression. The Buss-Perry Aggression Questionnaire (AQ) was used to evaluate level of aggression (Buss & Perry, 1992). This scale consists of 27 questions and 4 dimensions of aggression (physical aggression, verbal aggression, anger, and hostility). It is scored on a 5-point Likert scale, with scores ranging from 1 (never) to 5 points (very true). Total scores ranged from 27 to 135 points, with higher scores indicating higher levels of aggression. In this study, the internal consistency of this tool (Cronbach's α) was 0.89. The Korean version of the AQ was used in this study (Kwon & Seo, 2002).

Severity of IGD features. Severity of IGD features was assessed using the Internet Game Use-Elicited Symptom Screen (IGUESS). This instrument was created based on the nine DSM-5 IGD criteria, with each item rated on a 4-point scale: 0 = *strongly disagree*, 1 = *somewhat disagree*, 2 = *somewhat agree*, 3 = *strongly agree*. A higher score indicates greater severity of IGD features. This scale is reliable, with a Cronbach's alpha of 0.85 in the current study. Severity of IGD was considered to have a continuous severity dimension, in which higher scores on the IGUESS indicate greater severity (Jo et al., 2017).

Diagnosis of attention deficit and hyperactivity disorder. - ADHD was evaluated by each parent or guardian using the Diagnostic Interview Schedule for Children, Version 4 (DISC-IV) at wave 1. The DISC-IV is a highly structured diagnostic interview used to assess psychiatric disorders in children and adolescents. The DISC-IV was administered by trained interviewers at the participants' homes or in a private space at the school, based on each participant's preference.

Socio-demographics. General characteristics, including age, sex, and family type, were obtained from adolescents' self-reports, and socioeconomic status (SES) was determined based on parents' self-report assessments at wave 1. Regarding family type, an intact family was defined as children living with both parents; non-intact families included children living with only a mother or father or with neither parent because of divorce, death, or separation of their parents. SES was surveyed in seven stages, from 1 = lowest to 7 = highest and 1–4 was categorized as low to moderate and 5–7 to high in the analysis. Academic achievement was surveyed as 1 = very good, 2 = good, 3 = neural, and 4 = bad and 1–2 was classified as high academic achievement and 3–4 as low academic achievement in the analysis.

Statistical analysis. Descriptive data were summarized with numbers and percentages for categorical variables or mean ± SD and ranges for continuous variables stratified by gender. Pearson correlation analysis was performed to detect linear relationships among study variables stratified by gender. Before conducting the analysis, severity measures of IGD features were log-transformed to approximate normality. T-test was conducted to detect gender difference among study variables.

The relationships between levels of IHPs (exposure variable at wave 1) and severity of IGD (outcome variable at wave 3) mediated by low self-control (mediation model 1 at wave 1) and aggression (mediator 2 at wave 2) were evaluated using serial mediation analysis by PROCESS macro, version 3.3, model 6 (Hays, 2013). Serial multiple mediation assumes that a causal chain may link the mediators, with a specified direction of flow. In serial multiple mediation analysis, we estimate one direct effect and three indirect effects of the exposure variable on the outcome variable through mediator 1 and mediator 2 (Fig. 1). Path c represents the direct effect of the exposure variable on the outcome variable. Path a1 represents the effect of the exposure variable on mediator 1, and path a2 represents the effect of the exposure variable on mediator 2. Path a3 is the effect of mediator 1 on mediator 2. Path b1 and b2 represent the effects of mediator 1 and mediator 2, respectively on

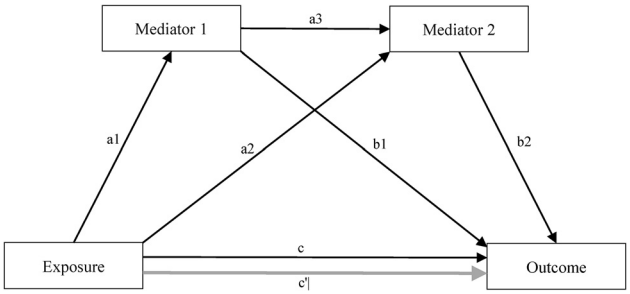

Fig. 1. Multiple serial mediation model. The relationships between IHPs (inattention and hyperactive problems) at wave 1 (exposure variable) and severity of IGD features at wave 3 (outcome variable) was investigated as being mediated by low self-control at wave 1 (mediator 1) and aggression at wave 2 (mediator 2). Path a1 represents the effect of exposure on mediator 1, and path a2 represents the effect of exposure on mediator 2. Path a3 is the effect of mediator 1 on mediator 2. Path b1 and b2 represent mediator 1 and mediator 2 on outcome, respectively. Path c represents the direct effect of exposure on outcome and Path c' is total effect

outcomes. The total effect of ADHD symptoms on severity of IGD features was quantified as the sum of the direct and indirect effects. The indirect effect of ADHD symptoms on severity of IGD features mediated by low self-control was quantified as a1 × b1, and the indirect effect of ADHD symptoms on severity of IGD features through aggression was quantified as a2 × b2. The indirect effect of ADHD symptoms on severity of IGD features through low self-control and high aggression was quantified as a1 × a3 × b2.

To test the significance of mediation effects, 5,000 bootstrap resamples were performed and the 95% confidence interval was determined. Bias-corrected confidence intervals that did not include 0 were considered significant to determine indirect effects. Effect size in mediation analysis was assessed in terms of standardized indirect effect size, indicating that outcome variables are expected to increase according to the magnitude of standard deviations of effect size for every one SD increase in exposure variable indirectly through mediators. Effect size was interpreted as small (0.01), medium (0.09), or large (0.25) (Preacher & Kelley, 2011). Serial multiple mediation analysis was performed separately for each gender. Potential confounding factors such as, age, family type, SES, and baseline IGD score were included as covariates in all mediation models using SPSS AMOS, version 23.0 (IBM Corp., Armonk, NY, USA).

Ethics

Written consent was acquired from both all participants and their parents or legal guardians following explanation of the nature of and principles of the research, including confidentiality and freedom of choice to participate. This study received a full review and approval from the Institutional Review Board of The Catholic University of Korea (MC19EAS10137). All procedures were performed in accordance with the Helsinki Declaration of 1975, as revised in 2013.

RESULTS

Demographic characteristics

Baseline demographic characteristics by sex are summarized in Table 1. Of 1,783 participants, 987 (57.0%) were male. No gender difference in age, family type and SES. Mean baseline IGD scores measured by the IGUESS were higher in men than in women ($P < 0.001$).

The correlations between study variables are shown in Table 2. Higher levels of IHPs (W1) were correlated with lower levels of self-control (W1) (men, $r = 0.18$, $P < 0.01$; women, $r = 0.18$, $P < 0.01$), higher levels of aggression (W2) (men, $r = 0.10$, $P < 0.05$; women, $r = 0.20$, $P < 0.01$), higher levels of IGD severity (W3) (men, $r = 0.13$, $P < 0.01$; women, $r = 0.17$, $P < 0.01$), lower levels of intact family (men, $r = -0.15$, $P < 0.01$; women, $r = -0.11$, $P < 0.05$), and higher levels of baseline IGD scores (men, $r = 0.16$, $P < 0.01$; women, $r = 0.13$, $P < 0.01$). Lower levels of self-control (W1) were correlated with higher levels of aggression (W2) (men, $r = 0.33$, $P < 0.001$; women, $r = 0.49$, $P < 0.001$), higher levels of IGD severity (W3) (men, $r = 0.23$, $P < 0.001$; women, $r = 0.23$, $P < 0.001$), and higher levels of baseline IGD scores (men, $r = 0.25$, $P < 0.001$; women, $r = 0.26$, $P < 0.001$). Higher levels of aggression (W2) were related to higher levels of IGD severity (W3) (men, $r = 0.25$, $P < 0.001$; women, $r = 0.23$, $P < 0.001$), and higher levels of baseline IGD scores (men, $r = 0.16$, $P < 0.001$; women, $r = 0.25$, $P < 0.001$). Men have higher level of IHP (W1), low self-control (W1), aggression (W2), and severity of IGD features (W3) than women.

The serial multiple mediation analysis is performed separately for each gender. Potential confounding factors such as, age, family type, SES, baseline IGD score were included in the model. Levels of IHPs (W1) directly affected

Table 1. Baseline characteristics of 1,732 iCURE study participants stratified by gender

Variables	Men (n = 987, 57%) n (%) or Mean ± SD	Women (n = 745, 43%) n (%) or Mean ± SD	*P*-value
Age	12.9 ± 0.2	12.8 ± 0.2	0.523
Family type			0.934
Intact	902 (91.4)	680 (91.3)	
Non-intact	85 (8.6)	65 (8.7)	
Socio-economic status			0.932
Moderate to high	695 (70.4)	526 (70.6)	
Low	292 (29.6)	219 (29.4)	
Academic achievement			0.461
Good	454 (46.0)	356 (47.8)	
Bad	533 (54.0)	389 (52.2)	
Baseline IGUESS score	4.3 ± 4.0	2.6 ± 3.6	<0.001

IGUESS: Internet Game Use-Elicited Symptom Screen.

Table 2. Correlations between study variables and measurement reliabilities stratified by gender

Variables	1	2	3	4	5	6	7		Mean ± SD[a]	Cronbach's alpha
Men										
1. IHPs (W1)	1								5.6 ± 5.3***	0.90
2. Low self-control (W1)	0.18**	1							17.3 ± 4.9***	0.82
3. Aggression (W2)	0.10*	0.33***	1						56.9 ± 14.6*	0.89
4. Severity of IGD features (W3)	0.13**	0.23***	0.25***	1					4.1 ± 4.0***	0.84
5. Socioeconomic status (W1)	−0.04	−0.02	−0.01	−0.06	1				NA	NA
6. Family type (W1)	−0.15**	−0.01	−0.01	−0.05	0.09*	1			NA	NA
7. Baseline IGD score (W1)	0.16**	0.25***	0.16**	0.32***	0.03	−0.02	1		4.3± 4.0	0.89
8. Low academic achievement (W1)	0.32***	0.12**	0.02	0.10*	−0.18**	−0.04	0.14**	1	NA	NA
Women										
1. IHPs (W1)	1								4.2 ± 4.8***	0.88
2. Low self-control (W1)	0.18**	1							16.2 ± 3.9***	0.76
3. Aggression (W2)	0.20***	0.49***	1						54.8 ± 13.0*	0.88
4. Severity of IGD features (W3)	0.17**	0.23***	0.23***	1					1.7 ± 3.0***	0.87
5. Socioeconomic status (W1)	−0.10	0.02	−0.03	0.04	1				NA	NA
6. Family type (W1)	−0.11*	−0.07*	−0.09*	−0.04	0.1	1			NA	NA
7. Baseline IGD score (W1)	0.13**	0.26***	0.25***	0.26***	−0.03	−0.07	1		2.6 ± 3.6	0.89
8. Low academic achievement (W1)	0.29***	0.12**	0.08	0.10*	−0.14**	−0.06	0.14**	1	NA	NA

IHP: inattention and hyperactivity problems; IGD: Internet gaming disorder; NA: not available; W1: wave 1; W2: Wave 2; W3: Wave 3. Family type was coded 0 = non-intact, 1 = intact; Socioeconomic status was coded 1 = moderate to high, 2 = low; Low academic achievement was coded 1 = no, 2 = yes.

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

[a]Group differences between men and women were calculated by t-test.

severity of IGD features (W3) only in women, but the association was small (c, women, coefficient: 0.09, $P < 0.05$). The indirect effects via low self-control (W1) (a1 × b1, men, coefficient: 0.014, 95% CI: 0.003–0.036; women, coefficient: 0.016, 95% CI: 0.006–0.043) were also significant in the relationship between IHP (W1) and severity of IGD features (W3) in both genders, however, the indirect effects via aggression (W2) (a2 × b2, women, coefficient: 0.015, 95% CI: 0.006–0.035) was significant only in women. The serial mediation effect between the levels of IHPs (W1) and severity of IGD features (W3) through low self-control (W1) via aggression (W2) was statistically significant but small in both genders (a1 × a2 × b2, men, coefficient: 0.009, 95% CI: 0.005–0.019; women, coefficient: 0.010, 95% CI: 0.005–0.026). The overall model explained 17% (in both men and women) of the total variance of severity of IGD features (W3) (men, F (4,982) = 51.51, $P < 0.001$; women, F (4,740) = 39.46, $P < 0.001$) (Fig. 2) (Table 3).

DISCUSSION

We investigated whether and how low self-control and high aggression may serially mediate relationships between levels of IHPs and severity of IGD features among adolescents without ADHD using three-wave longitudinal data. Our findings suggest that higher levels of IHPs are directly associated with severity of IGD features among adolescents without ADHD in both genders. Similarly, IHPs have been shown to increase the likelihood of exhibiting IGD symptoms in other age groups (Ferguson, 2011; Lemmens et al., 2011; Vadlin, Aslund, Hellstrom, & Nilsson, 2016). IHPs may be related to alterations within the brain's reward system associated with overestimations of the short-term value of gambling- or gaming-related rewards (Sethi, Voon, Critchley, Cercignani, & Harrison, 2018), and these may operate behaviorally through low self-control. Since online games offer many different forms of in-game reward-related reinforcement (Lorenz, Gleich, Gallinat, & Kuhn, 2015), adolescents with higher levels of IHPs might be more susceptible to the influence of reward-related stimuli, thus increasing the risk of IGD.

Our findings showed that higher levels of IHPs link prospectively to low self-control, which in turn indirectly impacts the severity of IGD features among adolescents without ADHD in both genders. This result was consistent with previous findings that self-control mediates the relationship between IHPs levels and IGD risk (Yen et al., 2017).

According to the dual systems (DS) model of the adolescent brain, risky, impulsive, sensation-seeking behavior in adolescence is the product of an interaction between two distinct brain circuits: the cognitive control system and the reward system (Casey & Caudle, 2013). Adolescence is a time of diminished capacity for self-control compared to adulthood, in part because of imbalance between these two systems. The cognitive control brain circuit is still developing and does not reach maturity until the early twenties (Cohen & Casey, 2014). This suggests that

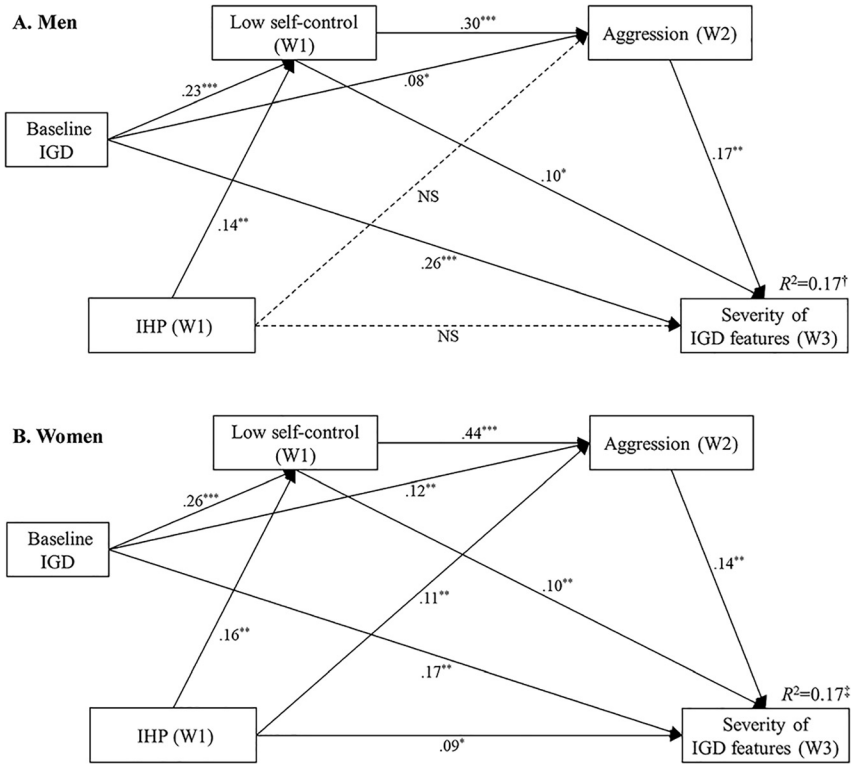

Fig. 2. The associations between levels of IHPs (inattention hyperactive problems) (wave 1) and severity of IGD features (wave 3) were investigated within each pathway in the serial mediation model. Each arrow with a solid line represents the significant path and dotted lines are insignificant between variables. The path estimation from the mediation analysis is shown with each arrow is the standardized coefficient after adjusting for age, family type, socio-economic status, academic achievement, and baseline IGD feature. $^{*}P<0.05$ $^{**}P<0.01$ $^{***}P<0.001$; $^{\dagger}F$ (4,982) = 51.51, $P < 0.001$; $^{\ddagger}F$ (4,740) = 39.46, $P < 0.001$

adolescents with IHPs may struggle to maintain self-control during gaming activity, which may increase the risk of IGD.

Our findings indicate that higher levels of IHPs link prospectively to high aggression, which in turn indirectly impacts the severity of IGD features in women; however, the indirect effect was not statistically significant in men. When it comes to the gender difference in mediating role of aggression, it can be explained by gender difference in neurodevelopment and parent's view's on behavioral problem. Adolescence is a period of continued brain growth and change and largely finished maturing by puberty (Mills et al., 2016). When hormones surge in puberty, the amygdala becomes more active, leading to emotional behavior. The prefrontal cortex regulates the amygdala to ensure socially correct behavior. But during adolescence, it still has maturing to do. Longitudinal studies have shown gender differences in brain development, with females reaching peak values of brain volumes earlier than males (Koolschijn & Crone, 2013). Since our participants were all seventh graders, the majority of women might have already reached puberty, but the men would not have reached puberty yet. Alternative explanation can be possible. Since IHP was evaluated by parents, it is possible that differing perceptions of behaviors and impairment in sons or daughters. Parents, in their own ratings, may under-rate IHP symptoms and impairment in girls compared to boys, suggesting sex-specific biases in perceptions of behavior (Mowlem, Agnew-Blais, Taylor, & Asherson, 2019).

Our findings indicate that higher levels of IHPs serially and prospectively link to low self-control and high aggression, which in turn impacts the severity of IGD features in adolescents without ADHD in both genders. Even though no studies have identified the mechanism underlying the serial mediation effects of low self-control and high aggression in the association between higher levels of IHPs and IGD symptom severity, empirical studies have repeatedly found significantly lower self-control and higher aggression among adolescents with IGD (Choo et al., 2010; Mehroof & Griffiths, 2010; Nuyens et al., 2016).

Youth with low self-control are more likely to commit aggressive crimes when they become adults (Mehroof & Griffiths, 2010). Associations between poor self-control and aggressive behavior were detected in the context of Gottfredson and Hirschi's General Theory of Crime (1990), which holds that poor self-control distinguishes aggressive criminal offenders from non-offenders (Gottfredson & Hirschi, 1990). Since adolescents with low self-control are more likely to show increased aggression and rule-breaking behavior, when exposed to online games and related rewards they may become sensitized and exhibit more features of IGD.

Table 3. Indirect and serial mediation paths in the relationships between levels of IHPs and severity of IGD features

Paths	β	SE	95% CI*
Men (n = 987)			
Levels of IHPs (W1) → Low self-control (W1) → Severity of IGD features (W3)	0.014	0.008	0.003 to 0.036
Levels of IHPs (W1) → Aggression (W2)→ Severity of IGD features (W3)	0.007	0.007	−0.007 to 0.023
Levels of IHPs (W1) → Low self-control (W1) → Aggression (W2) → Severity of IGD features (W3)	0.009	0.004	0.005 to 0.019
Women (n = 745)			
Levels of IHPs (W1) → Low self-control (W1) → Severity of IGD features (W3)	0.016	0.010	0.006 to 0.043
Levels of IHPs (W1) → Aggression (W2)→ Severity of IGD features (W3)	0.015	0.008	0.006 to 0.035
Levels of IHPs (W1) → Low self-control (W1) → Aggression (W2) → Severity of IGD features (W3)	0.010	0.005	0.005 to 0.026

IHPs: inattention and hyperactivity problems; IGD: Internet gaming disorder.
*95% CI is presented as bias-corrected and accelerated 5,000 bootstrapping.

Our results support the typology of IGD proposed by Lee et al. (2017), in which low self-control and high aggression are mediating factors in the relationship between IHPs and risk of IGD. In this context, gamers may become motivated to impulsively express aggression through excessive gaming (Lee et al., 2017). A previous study found that people with IHPs experience reduced activity in cortical regions associated with attention, impulse control, and stimulus-integration abilities (Sakai, Uchiyama, Shin, Hayashi, & Sadato, 2013). IHPs may contribute importantly to IGD via low levels of self-control and high levels of aggressive behavior. Neurodevelopmental mismatches in the frontostriatal system or dysfunctional neurotransmission may be the neurobiological mechanisms underlying these observations (Norman et al., 2018).

The current study has several strengths. First, we used three-wave longitudinal data to examine the serial mediation model. This made it possible to assume temporal precedence between variables (Preacher & Kelley, 2011). Second, we analyzed a homogeneous sample, in which all participants were seventh graders at baseline. The variables included in this model, such as IHPs, self-control, and aggression, are likely to be affected by hormones or brain development. Since the participants were within a limited age range, the effects of these biological factors may have been reduced. Finally, data to determine levels of IHPs were collected from parental reports, which may have reduced the influence of common method biases on our results because we collected information from multiple sources.

Despite these strengths, it is difficult to generalize our results to other populations because we did not include a broader sample of adolescents. It is necessary to include larger and more diverse samples to generalize study findings to adolescents more broadly. In addition, it is not possible to precisely determine the causal direction of serial mediation from low self-control to aggression explaining the effects of IHPs on severity of IGD features in the current study. The analyses cast the variables in a temporal order, based on the available literature and using a longitudinal dataset. However, without including all the variables measured at each time point in the model, the full causal pathways linking level of IHPs and severity of IGD features cannot be established. In addition, the effect sizes were very small.

CONCLUSION

In the current study, we provide the results that might explain the mechanism of how IHPs may impact severity of IGD features in adolescents without ADHD using three-wave longitudinal data. We revealed a possible mechanism underlying a serial mediation chain from low self-control to aggression explaining the effects of IHPs on severity of IGD features. Our findings highlight the importance of self-control and aggression in the relationship between IHPs and severity of IGD features among adolescents without ADHD. Thus, clinicians need to focus on enhancing self-control and reducing aggression when performing interventions to prevent IGD in individuals with high levels of IHPs. However, this conclusion should be taken with a caution, because the effect sizes were very low.

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Authors' contributions: HJ conducted the analyses and led the writing of the manuscript. HWY guided and supervised the writing of the manuscript. HJ and HWY developed and proposed the basic idea of the study. SL, HL, and MNP reviewed scientific content and edited the manuscript. HWY, HJ, SJ, HS, and GK contributed to conducting the study. All authors contributed editorial comments on the manuscript.

Conflict of interests: All authors declare that they have no competing interests except for Dr Potenza. Dr Potenza has consulted for and advised Game Day Data, the Addiction Policy Forum, RiverMend Health, Lakelight Therapeutics/Opiant and Jazz Pharmaceuticals. He has received research support from the Mohegan Sun Casino and the National

Center for Responsible Gaming (now the International Center for Responsible Gaming). He has participated in surveys, mailings, and telephone consultations related to drug addiction, impulse control disorders, and other health topics, and has consulted for law offices and gambling entities on issues related to impulse control and addictive disorders.

Data Availability: The datasets generated and/or analyzed during the current study are available from the corresponding author.

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