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Risk factors and outcomes of internet gaming disorder identified in Korean prospective adolescent cohort study

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FULL-LENGTH REPORT

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ABSTRACT

Background and aims: Internet gaming disorder (IGD) is known to cause various psychological and physical complications. Through data collected from an adolescent prospective longitudinal cohort, we examined how IGD is related to lifestyle and physical symptoms, as well as the temporal relationship between them. *Methods:* This study was conducted as part of iCURE (Internet user Cohort for Unbiased Recognition of gaming disorder in Early Adolescence) in Korea between 2015 and 2019. Sleep and physical activity time, dry eye symptoms, musculoskeletal pain, and near-miss accidents were measured at baseline and followed-up after one year. IGD risk was evaluated using the Internet Game Use – Elicited Symptom Screen (IGUESS). The association between IGD risk and measured variables was analyzed, both at baseline and at follow-up after one year. *Results:* At baseline, the IGD risk group had significantly less physical activity time and sleep time and had more dry eye symptoms, musculoskeletal pain, and near-miss accidents than the IGD non-risk group. Additionally, in the IGD risk group at baseline, dry eye symptoms, musculoskeletal pain, and near-miss accidents occurred significantly more after one year of follow-up. *Discussion and conclusion:* The results of this study show that IGD is a significant risk factor that increases the probability of physical disease and trauma in adolescents. Therefore, interventions aimed at reducing IGD risk and protecting the physical and mental health of adolescents are imperative.

KEYWORDS

internet gaming disorder, adolescent physical symptoms, adolescent physical activity

INTRODUCTION

Internet gaming disorder (IGD) is becoming increasingly prevalent worldwide with the development of technology (Feng, Ramo, Chan, & Bourgeois, 2017). IGD consists of a behavioral pattern associated with persistent and repeated engagement in online and offline games, which results in significant impairment or distress over a period of 12 months (American Psychiatric Association, 2013). According to the diagnostic criteria of IGD, at least 5 of the following 9 must be met: (1) a preoccupation with gaming; (2) withdrawal symptoms when gaming is taken away; (3) tolerance, resulting in the need to spend increasing amounts of time engaged in gaming; (4) unsuccessful attempts to control or quit gaming; (5) loss of interest in previous hobbies and entertainment as a result of, and with the

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exception of, gaming; (6) continued excessive use of games despite awareness about the psychosocial problems it causes; (7) deceiving family members, therapists, or others regarding the amount of gaming; (8) the use of games to escape or relieve negative moods; and (9) jeopardizing or losing a significant relationship, job, education, or career opportunity due to gaming (American Psychiatric Association, 2013).

Additionally, in 2018, a new category "Gaming Disorder, predominantly online gaming disorder" was added in ICD-11, which provides worldwide criteria for diagnosing diseases. This disorder is characterized by a pattern of persistent or recurrent gaming behavior ("digital gaming" or "video-gaming") that is primarily conducted over the internet and is manifested by impaired control over gaming (e.g., onset, frequency, intensity, duration, termination, context); increasing priority given to gaming to the extent that gaming takes precedence over other life interests and daily activities; and continuation or escalation of gaming despite the occurrence of negative consequences. The behavior pattern is of sufficient severity to cause significant impairment in personal, family, social, educational, occupational, or other important areas of functioning (World Health Organization (WHO), 2022).

As presented in the diagnostic criteria of DSM and ICD, IGD is an excessive absorption in games, causing restrictions in academic achievement and interpersonal relationships. Therefore, the negative effect of IGD is greater in adolescence, when physical and mental development must be achieved (Sugaya, Shirasaka, Takahashi, & Kanda, 2019). In addition, the prevalence of IGD is higher in adolescence than in other periods as it is characterized by rapid adoption of new technologies and a high tendency to pursue novel developments (Odgers & Jensen, 2020).

Previous studies have shown IGD to be associated with loneliness (Wang, Sheng, & Wang, 2019), anxiety (Wang et al., 2017), depression (Wang, Cho, & Kim, 2018), lower academic achievement (Hawi, Samaha, & Griffiths, 2018), conduct problem (Brunborg, Mentzoni, & Frøyland, 2014), sleep difficulties (Wong et al., 2020), and lower psychosocial well-being (Pappa, Apergi, Ventouratou, Janikian, & Beratis, 2016). Decreased physical activity (Henchoz et al., 2016) and physical symptoms, such as pain in the wrist joints, were also found to be significantly associated with IGD (Gentile, 2009). Studies have also found IGD to be related to obesity (Mallorquí-Bagué et al., 2017), neck pain (Cankurtaran et al., 2022), hearing problems (Bener et al., 2019), and eye discomforts (Lee, Cho, Moon, Kim, & Yu, 2019). IGD has also been linked to impulsivity (Kim et al., 2016), and in the case of augmented reality (AR), which has gained immense popularity in recent times among adolescents, IGD is also associated with the risk of injury or accident by blocking attention from stimuli other than games (Mukhra, Baryah, Krishan, & Kanchan, 2019). According to a study conducted on the cost-benefit of gaming in Korea, the cost of gaming itself (excess game spending, crime, counseling, etc.) accounts for 14% of the total benefit due to negative outcomes. However, in gaming addiction, the ratio increases to 95% (Cho, Kim, Lee, & Park, 2018). Therefore, it is necessary to prevent and manage IGD from a socio-economic point of view.

To reduce the negative effects of IGD, appropriate interventions are needed in adolescence, when IGD is known to occur frequently and is likely to induce long-term effects. To achieve this goal, it is necessary to distinguish between the risk factors that cause IGD and the outcomes of IGD. However, most previous studies including those mentioned above on the association between IGD, sleep, physical activity, and physical symptoms have been based on cross-sectional designs (Cankurtaran et al., 2022; Gentile, 2009; Henchoz et al., 2016; Lee et al., 2019; Mukhra et al., 2019; Pappa et al., 2016; Wong et al., 2020). Therefore, it provides insufficient evidence for temporal relationships and to infer causal relationships. To overcome this limitation, our study intends to identify the temporal relationships between IGD and sleep, physical activity, and physical symptoms through a prospective cohort study of Korean adolescents followed-up after a one-year interval. In this process, information on potential confounding variables was collected and adjusted to minimize unpredicted biases.

Based on these data, we hypothesize that IGD has a significant association with sleep problems, physical inactivity, and physical symptoms and tested the hypotheses. Further, with IGD, these symptoms are expected to increase over time.

METHODS

Study design and participants

The Internet user Cohort for Unbiased Recognition of Gaming Disorder in Early Adolescence (iCURE) study is a multidisciplinary, prospective, longitudinal cohort study of adolescents, conducted in Korea, with four waves of annual data collection currently planned. The study was conducted in Seoul and Uijeongbu, Gyeonggi Province, with third, fourth, and seventh-grade students. To proceed with the research, we requested three offices of educational support: the Seoul Southern offices of educational support, the Seoul Northern offices of educational support, and the Gyeonggi Province offices of educational support. We sent an official letter to the elementary and middle schools within the jurisdiction of each Office of Education. Among the 258 elementary/junior high schools that sent the official letter, 6 elementary schools and 15 junior high schools that wanted to participate in the study recruited study subjects (Jeong et al., 2020). If they agreed to participate in the survey, they were enrolled as a cohort. Through this process, 2,319 of 4,794 students from 21 schools were enrolled in the cohort. (Participation rate 48.4%) Using the computer room of the school, each participant used a personal computer to respond to the online self-report questionnaire during available regular class hours. Written parental consent and participant consent is mandatory for participation following the explanation of the nature of the principles of research, including confidentiality and the freedom of choice to participate in the study (Jeong et al., 2020). In the present study, we used the baseline evaluation (in 2015) and one-year follow-up (in 2016) data.

Measures and procedures

Assessment of sociodemographic factors. Demographic characteristics were assessed at baseline. Gender, date of birth, school level, and personal smartphone use were obtained from the student assessment; socioeconomic status and academic records were obtained from the parent or guardian assessments.

Assessment of IGD risk (Internet Game Use – Elicited Symptom Screen: IGUESS). This instrument was created based on the nine DSM-5 IGD criteria. Students were instructed to respond based on their gaming behavior over the previous 12 months, with each item rated on a 4-point scale: 1 = not at all, 2 = occasionally, 3 = frequently, and 4 = always. The sensitivity and specificity of IGUESS were 87.0% and 86.7%, respectively, for a cut-off score of 10 points, with an area under the curve value of 0.93. Its reliability, as determined by Cronbach's alpha, was 0.94, and the correlation coefficient between IGUESS and Young's Internet Addiction Test was $r = 0.902$ (Jo et al., 2018). Based on a previous study, participants with a score of 10 or higher on the IGUESS were defined as the IGD risk group.

Assessment of physical health status. We assessed physical pain experiences, such as in the hand, wrist, shoulder, or neck; dry eyes with the 11 symptoms questionnaire. For obtaining data on physical pain experience, Musculoskeletal Disease Symptom Survey tool (Kim, Park, & Kim, 2008) was used to investigate whether pain was experienced in parts of the body that could be affected during repetitive work involving the same movement, such as working on a computer. Through this, when at least one of the body parts (1. hand, finger, or wrist, 2. shoulder, 3. neck) was found to experience pain, and the response was "yes," the person was considered to experience musculoskeletal pain. Further, a self-check list for dry eye symptoms provided by the Korea Public Health Information Service (https://www.g-health.kr/mobile/bbs/selectBoardArticle.do?bbsId=U00194&nttId=193255&lang=&searchCndSj=&searchCndCt=&searchWrd=&pageIndex=1&vType=&option7=11) was used. Further, 3 or more of 11 symptoms were defined as symptomatic through the expert consensus of 3 ophthalmologists. The 11 symptoms included in the self-check list are as follows: 1. There is a feeling of a foreign body such as a grain of sand having entered the eye. 2. My eyelids feel heavy and my head hurts. 3. My eyes are stiff. 4. It appears as if there is a curtain in front of my eyes. 5. My eyes get tired easily and I can't read for a long time. 6. When the wind blows, my eyes tear up. 7. My eyes become bloodshot frequently for no reason. 8. On waking up from sleep, my eyelids stick together, and it is difficult to open them. 9. My eyes keep closing when there is a glare. 10. I feel like my eyes are pouring (falling out). 11. Thread-like discharge keeps coming out.

3. Physical exercise: We also asked whether participants exercised regularly – two times or more per week and 30 min or more at a given time, excluding activities of the school curriculum based on previous Korean guidelines (Ministry of Health & Welfare of Korea, 2013). School physical education hours in elementary and junior high schools in Korea follow the curriculum stipulated by the Ministry of Education and are excluded from the measurement because they are the same at about 4 h per week in all schools. The rate of lack of physical activity among Korean adolescents has touched 95% in 2020 (Korea Centers for Disease Control and Prevention, 2021). Because most of the urban adolescents in Korea, who are competing under pressure for academic achievement, lack physical activity, it was judged that using the absolute value of the recommended physical activity standard as a cut-off point in this study was limited. The Korean National Health and Nutrition Examination Survey at the time of data collection defined regular exercise as when vigorous physical activity was more than 20 min at a time and 3 times a week (Korea Centers for Disease Control and Prevention, 2022). Data were collected by adjusting the frequency to at least 30 min and at least twice a week, a total of 60 min of physical activity per week. We expected this method to minimize the measurement error, because the authors judged that it is easier to accurately recognize and respond to "30 min or longer" rather than "20 min or longer."

Information on sleep hours during the week and during weekends was also sought. The average daily sleep time was obtained by calculating (weekday sleep time $\times$ 5) + (weekend sleep time $\times$ 2)/7. As of 2020, the average amount of sleep derived by junior high school students in Korea was 6.9 h, according to the online survey on health behavior of Korean adolescents (https://www.kdca.go.kr/yhs/). Further, from the results of a previous study, 7 h was suggested as the margin of the appropriate sleep time category for teenagers (Hirshkowitz et al., 2015). In this background, sleep hours were dichotomized into <7 h and ≥7 h on analyses according to the sleep duration recommendation of a previous study (Chaput, Dutil, & Sampasa-Kanyinga, 2018). Additionally, information was sought on whether there were near misses or accident experiences due to smartphone use over the previous 12 months.

Statistical analysis

The adjusting variables, gender, school level (elementary or junior high school), parents' subjective economic status (low/middle/high), and personal smartphone use (yes/no) were categorized, and each number and ratio were calculated. Independent variables, baseline and one-year follow up IGD risks, were also calculated as the number and ratio. The main dependent variables were regular exercise (physical activity at least twice a week and at least 30 min a day), sleep duration on weekdays and weekends (sleep more than 7 h a night or not), dry eye symptoms (3 or more specific symptoms), musculoskeletal pain (yes/no), and near or miss accidents (yes/no) were also categorized to calculate the number and ratio at baseline and one-year follow-up.

Subsequently, multiple logistic regression analyses were performed with baseline IGD risk as an independent variable, and baseline regular exercise, weekdays and weekend sleep duration, dry eye symptoms, musculoskeletal pain symptoms, and near-miss accidents as the dependent variables. The odds ratios (ORs) between positive IGD risk and each dependent variable were calculated with negative IGD risk as a reference. Moreover, in order to see the longitudinal effect of IGD, multiple logistic regression analyses were performed with baseline IGD risk as independent variable and the incidence of new physical symptoms, regular exercise, and sleep duration over 7 h during one year from baseline, as dependent variables. The incidence rate ratio (IRR) was calculated to determine the effect size.

Next, to determine the effect of changes in IGD risk on physical symptoms, physical activity, and sleep; participants were divided into (1) non-IGD → non-IGD, (2) IGD → non-IGD, (3) non-IGD → IGD, and (4) IGD → IGD groups. Multiple logistic regression analyses were performed with the IGD risk change group as the independent variable and with the incidence of new physical symptoms, physical activity, and sleep between the baseline and follow-up as the dependent variables with group (1) as a reference. In these analyses, gender, school level, economic status, personal smartphone usage, and academic records were adjusted. To prevent overfitting, only adjusting variables with a P value of less than 0.10 were used in the final analysis model.

Finally, in order to check the interaction between sleep, physical activity, and IGD risk, after stratifying the participants according to regular exercise, chi-square tests were performed to determine the correlation between sleep time and IGD risk.

Ethics

All procedures performed in studies involving human participants were in accordance with the ethical standards of the Institutional Review Board of the Catholic University of Korea (approval number: MC140NM10085) and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Written consent was received from all participants and from one of the participants' parents, or caregivers following an explanation of the study, including confidentiality and freedom of choice to participate.

RESULTS

At baseline we registered 2,319 participants, of which 1951 had played Internet games within the past 12 months. Among them, a one-year follow-up was completed with 1849 participants, of which 1838 were included (excluding 11 missing health outcomes or IGD risk). There was no significant difference in the follow-up rate according to the exposure variable at the base time, that is, the presence of IGD. Further, there was no difference in the distribution of follow-up rates according to each health outcome group at baseline. In the case of follow-up rates by other general characteristics, there were no significant differences in any variable other than the school level. In the case of school level, junior high students showed a slightly higher follow-up rate than elementary school students, but they were treated as adjustment variables during multiple logistic analysis. The risk of selection bias is considered to be minimal (Appendix Table A1). Among the groups where follow-up was completed, 64.3% were male and 81.9% were junior high school students. The group that used personal smartphones accounted for 85.4% of the participants. The IGD risk group evaluated by IGUESS was 8.8% at baseline and 7.8% at one-year follow-up (Table 1).

The main variable of interest; dry eye symptoms were 22% and 20.2% at baseline and follow-up, respectively. Musculoskeletal pain was observed in 43.8% and 51.4% of patients at baseline and follow-up, respectively. Near-miss accidents were both 16.9% at baseline and at follow-up. Regular exercise at baseline was 58.3% and 48% after one-year of follow-up. The group with sleep less than 7 h per week was 9.2% at baseline and 16.5% at follow-up. On weekends, the baseline and follow-up were 5.5% and 5.2%, respectively (Table 2).

Regression analysis with baseline IGD risk as an independent variable and health outcome as a dependent variable, dry eye symptoms (OR = 3.07, 95% CI: 2.18–4.31), musculoskeletal pain (OR = 2.07, 95% CI: 1.49–2.89) and near miss accidents (OR = 3.27, 95% CI: 2.27–4.71) revealed a significantly positive association. On the other hand, in the IGD risk group, the ORs of the group that perform regular exercise (OR = 0.59, 95% CI = 0.42–0.83) and the group

Table 1. General characteristics at baseline (N = 1838)

Variable		n	(%)
Gender			
Female		656	35.7
Male		1,182	64.3
School level			
Elementary school		332	18.1
Middle school		1,506	81.9
Parents' subjective economic status			
Low		333	18.1
Middle		986	53.6
High		519	28.2
Personal smartphone use			
No		269	14.6
Yes		1,569	85.4
Subjective school achievement			
Good or very good		920	50.1
Fair or poor		918	49.9
Internet gaming disorder risk			
Baseline	Negative	1,676	91.2
	Positive	162	8.8
After 12-month	Negative	1,694	92.2
	Positive	144	7.8

Table 2. Status of Internet gaming disorder risk and health outcomes at baseline and 12-month follow-up (N = 1,838)

Variable		Baseline		12-month follow-up	
		n	(%)	*n*	(%)
Regular Exercise[a]					
No		766	41.7	956	52.0
Yes		1,072	58.3	882	48.0
Sleeping duration					
Weekday	<7hr/night	170	9.2	304	16.5
	≥7hr/night	1,668	90.8	1,534	83.5
Weekend	<7hr/night	102	5.5	95	5.2
	≥7hr/night	1,736	94.5	1,743	94.8
Dry eye symptoms					
Two symptoms or less		1,433	78.0	1,466	79.8
Three symptoms or more		405	22.0	372	20.2
Musculoskeletal pain symptom					
No		1,033	56.2	893	48.6
Yes		805	43.8	945	51.4
Near miss/accident					
No		1,527	83.1	1,528	83.1
Yes		311	16.9	310	16.9

[a]Two times or more per week and 30 min or over per time, except for activities of school curriculum.

that sleeps more than 7 h a day (OR = 0.48, 95% CI: 0.31–0.76) were significantly lower. However, there was no significant association between IGD risk and weekend sleep duration. Regression analysis with baseline IGD risk as an independent variable and new incidences of main interest variables during one-year follow-up as dependent variables, dry eye symptoms (IRR = 2.19, 95% CI: 1.31–3.67), musculoskeletal pain (IRR = 1.81, 95% CI: 1.10–2.98) and near-miss accidents (IRR = 1.94, 95% CI: 1.18–3.17) revealed a significantly positive association. However, there was no significant association between IGD risk, regular exercise, and daytime or weekend sleep (Table 3).

The associations between the IGD risk change during the follow-up period and the new incidence of main interest variables were compared as stratified groups: 1) non-IGD → non-IGD group, 2) IGD → non-IGD group, 3) non-IGD → IGD group, and 4) IGD → IGD group. At IGD → IGD group, the incidence of dry eye symptoms (IRR = 4.77, 95% CI: 1.84–12.35), and of near miss accidents (IRR = 2.73, 95% CI: 1.24–5.99) increased significantly, whereas there was no significant association with weekday/weekend sleep time and musculoskeletal pain. There was also a significant decrease in regular exercise in the non-IGD → IGD group (IRR = 0.48, 95% CI: 0.27–0.84) but not in the IGD → IGD group (Table 4).

In the stratified analysis according to regular exercise, IGD risk was lower in the group with short weekday sleep time compared to long weekday sleep time in regular exercisers. (6.8% vs 15.6%, P = 0.006). However, this correlation was not significant in the case of non-regular exercisers (9.7% vs. 17.5%, P = 0.052) (Table 5).

DISCUSSION

In this study, IGD risk had a significantly positive association with baseline physical symptoms (dry eye symptoms, musculoskeletal pain, and near-miss accidents). It also significantly increased new incidence during follow-up. IGD risk was also found to significantly affect sleep time during the week and regular exercise at baseline, but the effects on incidence during follow-up were not significant. When participants were classified into groups according to the change in IGD risk during follow-up, in the group with IGD risk both at baseline and follow-up, the incidence of physical symptoms significantly increased compared to other groups. However, the effects of regular exercise and sleep time during the week were not significant. When we checked the interaction effect between IGD risk, sleep, and exercise; regular exercise was negatively correlated with IGD risk when there was enough sleep time during the week, whereas this correlation was not significant when the sleep time during the week was insufficient.

In previous studies, it was reported that psychiatric symptoms (Hygen et al., 2020) and physical symptoms (Aziz, Nordin, Abdulkadir, & Salih, 2021) were more common in the group with Internet gaming disorder. However, some reports suggest that games are used as self-medication to cope with real life stressors (Bowditch, Naweed, & Chapman, 2019). Other studies also suggest that games enhance creativity and cognitive performance (Jackson et al., 2012; Ruiz-Ariza, Casuso, Suarez-Manzano, & Martínez-López, 2018). Hence, confirmatory evidence on negative health effects of IGD has been lacking until now. Further, some researchers argue that the IGD diagnosis of DSM-5 overpathologizes gaming and lowers the validity of the diagnosis (Király, Griffiths, & Demetrovics, 2015). As evidence supporting this, a study result has shown that many of the people diagnosed with behavioral addiction, a higher concept of IGD, were transient users who improved over time (Konkolÿ Thege, Woodin, Hodgins, & Williams, 2015). To find an answer to these issues, it is necessary to examine the longitudinal effect of excessive game use. In this study, in the IGD risk group, the prevalence of physical symptoms at baseline was high, and the incidence also increased after one-year of follow-up. In addition, the highest IRRs of physical symptoms were observed in the group with IGD risk at both baseline and follow-up, indicating a temporal precedence relationship that IGD risk induces and aggravates negative physical outcomes.

In previous studies, Internet gaming disorder was associated with short sleep duration and lack of exercise (Alshehri & Mohamed, 2019; Bener et al., 2019). This study replicated these results. However, unlike physical symptoms, this association was no longer significant in the longitudinal analyses. Therefore, we could infer that IGD risk, sleep, and physical activity are more likely to interact with each other rather than having an antecedent or causal relationship. Supporting this inference, sleep time and exercise in this

Table 3. Cross-sectional and longitudinal effect of Internet gaming disorder risk on health outcomes: multiple logistic regression results

Health outcomes IGD risk		Regular exercise[a]		Sleep duration-weekdays (≥7hr/night)[b]		Sleep duration-weekend (≥7hr/night)[b]		Dry eye symptoms[c]		Musculoskeletal pain symptoms[d]		Near accidents[e]	
		n (%)	IRR (95%CI)	n (%)	IRR (95%CI)	n (%)	IRR (95%CI)	n (%)	IRR (95%CI)	n (%)	IRR (95%CI)	n (%)	IRR (95%CI)
Cross-sectional effect													
IGD risk	Negative	991 (49.1)	Ref.	1,534 (91.5)	Ref.	1,588 (94.7)	Ref.	335 (20.0)	Ref.	711 (42.4)	Ref.	252 (15.0)	Ref.
	Positive	81 (50.0)	0.59 (0.42–0.83)	134 (82.7)	0.48 (0.31–0.76)	148 (91.4)	0.74 (0.41–1.34)	79 (43.2)	3.07 (2.18–4.31)	94 (58.0)	2.07 (1.49–2.89)	59 (36.4)	3.27 (2.27–4.71)
Longitudinal effect													
IGD risk	Negative	664 (67.0)	Ref.	1,344 (87.6)	Ref.	1,525 (96.0)	Ref.	175 (13.0)	Ref.	370 (38.3)	Ref.	177 (12.4)	Ref.
	Positive	51 (63.0)	0.75 (0.46–1.22)	113 (84.3)	0.84 (0.51–1.39)	141 (95.3)	0.96 (0.43–2.14)	23 (25.0)	2.19 (1.31–3.67)	37 (54.4)	1.81 (1.10–2.98)	23 (22.3)	1.94 (1.18–3.17)

[a] Adjusted for sex, school level, economic status, personal smartphone use; [b] Adjusted for sex, school level, economic status, personal smartphone use, academic records; [c] Adjusted for sex, school level, economic status, personal smartphone use, and academic records; [d] Adjusted for sex, school level, economic status, personal smartphone use, academic records and regular exercise; [e] Adjusted for sex, school level, economic status, personal smartphone use, academic records.

Table 4. Longitudinal association between change of Internet gaming disorder risk and health outcomes at 12-month follow-up

Health outcomes Change of IGD risk (baseline →12-month f/u)	Regular exercise[a]		Sleep duration-weekdays (≥7hr/night)[b]		Sleep duration-weekend (≥7hr/night)[b]		Dry eye symptoms[c]		Musculoskeletal pain symptoms[d]		Near accidents[e]	
	n (%)	IRR (95%CI)	n (%)	IRR (95%CI)	n (%)	IRR (95%CI)	n (%)	IRR (95%CI)	n (%)	IRR (95%CI)	n (%)	IRR (95%CI)
Non-IGD→Non-IGD	633 (67.6)	Ref.	1,275 (87.7)	Ref.	1,441 (96.1)	Ref.	205 (19.0)	Ref.	347 (37.7)	Ref.	154 (11.4)	Ref.
IGD→Non-IGD	32 (59.3)	0.63 (0.35–1.12)	74 (85.1)	0.88 (0.47–1.63)	97 (96.0)	1.00 (0.36–2.83)	18 (33.3)	2.07 (1.14–3.76)	25 (52.1)	1.67 (0.93–3.00)	14 (20.3)	1.88 (1.01–3.47)
Non-IGD→IGD	31 (56.4)	0.48 (0.27–0.84)	69 (85.2)	0.76 (0.40–1.46)	84 (95.5)	0.91 (0.32–2.59)	25 (49.0)	4.50 (2.51–8.06)	23 (51.1)	1.69 (0.92–3.09)	23 (31.5)	3.48 (2.05–5.90)
IGD→IGD	19 (70.4)	0.94 (0.40–1.98)	39 (83.0)	0.73 (0.33–1.61)	44 (93.6)	0.64 (0.19–2.12)	9 (50.0)	4.77 (1.84–12.35)	12 (60.0)	2.39 (0.96–5.95)	9 (26.5)	2.73 (1.24–5.99)

[a] Adjusted for sex, school level, economic status, personal smartphone use; [b] Adjusted for sex, school level, economic status, personal smartphone use, academic records; [c] Adjusted for sex, school level, economic status, personal smartphone use, and academic records; [d] Adjusted for sex, school level, economic status, personal smartphone use, academic records and regular exercise; [e] Adjusted for sex, school level, economic status, personal smartphone use, academic records.

Table 5. Stratified correlation analysis between IGD risk as sleep duration according to physical activity

Stratified group	Sleep duration-weekdays (<7hr/night) n (%)	Sleep duration-weekdays (≥7hr/night) n (%)	*P* value	Sleep duration-weekend (<7hr/night) n (%)	Sleep duration-weekend (≥7hr/night) n (%)	*P* value
Regular exerciser	14 (15.6%)	67 (6.8%)	*0.006*	8 (12.1%)	73 (7.3%)	0.149
Non-regular exerciser	14 (17.5%)	67 (9.8%)	0.052	6 (16.7%)	75 (10.3%)	0.259

[a]Regular exerciser: Two times or more per week and 30 min or over per time, except for activities of school curriculum.

study interacted with each other and had a significant effect on IGD risk.

As suggested in previous studies and also confirmed in this study, IGD risk can have a negative effect on the physical health of adolescents. Therefore, assessment of IGD risk and active intervention to prevent and treat IGD are much required (Rumpf et al., 2018). According to the results of this study, sleep and exercise were significantly associated with IGD risk. In particular, sufficient sleep time and regular exercise significantly lowered the IGD risk. Hence, improvement in sleep habits, regular physical activity, and healthy environments are important aspects to be considered when planning IGD prevention and treatment for adolescents.

The strength of this study is that it minimizes selection bias with a retention rate of approximately 94.8% during one-year follow-up as a longitudinal design. Thus, it was possible to clarify the temporal relationship between the variables, and it could further be used as evidence to reveal the causal relationship. In addition, it was possible to draw the conclusion that IGD risk independently increases the risk of physical symptoms by correcting various confounding variables collected from participants and their parents. However, this study has its limitation in that IGD risk was evaluated using a self-reporting questionnaire. Although this study was conducted anonymously, it is known that adolescents tend to underreport their Internet game use (Jeong et al., 2020). Hence, there might be a possibility that IGD risk was underestimated compared to the actual prevalence. However, the IGUESS, which was used to evaluate the IGD risk, has been proven to have sufficient reliability and validity in a previous study targeting Korean adolescents (Jo et al., 2018). Therefore, we can assume that the limitations of the self-report scale have been overcome to some extent. Another limitation of this study is that the target participants were evaluated only at certain schools in Seoul (the capital city of Korea) and nearby areas. Therefore, this may not be sufficiently representative of all adolescents in Korea. In this study design, to increase retention probability, it was difficult to include multiple schools, however, this can be supplemented in future national youth cohort studies. Another limitation is that in this study, outcomes such as exercise, sleep, and physical symptoms were analyzed in dichotomies, and the obtained information was not sufficiently utilized for analysis. However, expressing health status as a dichotomous variable has the advantage of being easy to interpret, and hence, it is widely used in medical research. According to previous studies, "only small differences in power and efficiency were evident. These small differences are related to the relatively large sample size" (Manor, Matthews, & Power, 2000). Considering the number of samples in this study, the effect of such information loss on the results is not significant. Further, in this cohort study, the focus of attention was on whether IGD affects the "occurrence" of the problem rather than "how much change it brings to each physical health state." This is the reason for dichotomous variables used for each physical health problem.

CONCLUSION

Internet gaming disorder (IGD) induces various physical symptoms in adolescents has been well established. Sleep and exercise interact with each other and are significantly associated with IGD risks. We expect the results of this study to be useful for clinical intervention in adolescents' IGD and toward establishing a national gaming policy.

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Authors' contribution: Gihwan Byeon, Sun-Jin Jo, and Hyeon-Woo Yim conceived and designed the work as well as drafted the manuscript. They also played important roles in interpreting the results and revised the manuscript. Hyunsuk Jeong, Hae Kook Lee and Jong-Ik Park acquired data, analyzed them, and revised the manuscripts. All authors read and approved the final version.

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Appendix

Table A1. Follow-up rate according to the baseline characteristics of participants ($N = 1,951$)

Baseline characteristics		Assessed at 12-month ($n = 1,838$)		Lost to follow-up ($n = 113$)		
		n	(%)	n	(%)	P
Exposure						
Internet gaming disorder risk						
Negative		1,676	94.1	105	5.9	0.526
Positive		162	95.3	8	4.7	
Outcomes						
Regular Exercise[a]						
No		733	94.2	47	5.8	0.986
Yes		1,072	94.2	66	5.8	
Sleep duration						
Weekday	<7hr/night	170	95.5	8	4.5	0.452
	≥7hr/night	1,668	94.1	104	5.9	
Weekend	<7hr/night	102	92.7	8	7.3	0.478
	≥7hr/night	1,736	94.3	104	5.7	
Dry eye symptoms						
Two symptoms or less		1,433	94.6	82	5.4	0.181
Three symptoms or more		405	92.9	31	7.1	
Musculoskeletal pain symptom						
No		1,033	93.4	73	6.6	0.080
Yes		805	95.3	40	4.7	
Near miss/accident						
No		1,527	94.3	93	5.7	0.847
Yes		311	94.5	18	5.5	
General characteristics						
Gender						
Female		656	95.1	34	4.9	0.227
Male		1,072	93.7	79	6.3	
School level						
Elementary school		332	91.2	32	8.8	0.007
Middle school		1,506	94.9	81	5.1	
Parents' subjective economic status						
Low		333	93.3	24	6.7	0.288
Middle		986	95.0	82	5.0	
High		519	93.3	37	6.7	
Subjective school achievement						
Good or very good		920	93.6	63	6.4	0.240
Fair or poor		918	94.8	50	5.2	
Personal smartphone use						
No		269	93.1	20	6.9	0.374
Yes		1,569	94.4	93	5.6	

[a] Two times or more per week and 30 min or over per time, except for activities of school curriculum.