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Relationship between adolescent gaming addiction and myopia, ocular surface condition, and health status: a questionnaire based cohort study

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This study explores the relationship between gaming addiction among Chinese adolescents and their myopia, ocular surface conditions, and overall health. A cross-sectional questionnaire-based cohort study included 835 participants aged 13–17, selected from 3300. Tools included the Hospital Anxiety and Depression Scale (HADS), Van Dream Anxiety Scale (VDAS), 36-Item Short-Form Health Survey (SF-36), Ocular Surface Disease Index (OSDI), Internet Addiction Test (IAT), and Internet Gaming Disorder Scale-20 (IGD-20). Linear regression, Pearson correlation, and unpaired *t*-tests were used. Gaming addiction correlated with worsened physical and mental health. Older age and longer gaming duration were linked to higher myopia rates. Males scored higher on HADS, VDAS, IAT, and IGD-20 but lower on SF-36 than females. Myopic gamers had longer gaming durations and higher IAT scores. IGD-20 scores for gamers playing 5–6+ hours daily showed stronger correlations with HADS, VDAS, and OSDI. Online gaming significantly impacts vision, physical and mental health, and ocular surface conditions. Score differences between groups underscore the need for interventions, including mental health support, cognitive-behavioral correction, and preventive eye care.

Keywords Internet game addiction, Adolescents, Myopia, Ocular surface, Psychological health, Physical health

In the tide of the digital age, electronic games have become one of the most popular leisure activities for teenagers. The digital age has brought new challenges to children and adolescents. Among these challenges, the problem of addiction to online games has received widespread attention from society, schools, and families[1]. Addiction to online games can lead to decreased academic performance, poor adaptation, and psychological health problems among children and adolescents[2]. The World Health Organization (WHO) has classified gaming addiction as a mental health disorder and included it as an official disease in the International Classification of Diseases (ICD). The diagnostic criteria[3] include: complete focus on gaming, feeling uncomfortable when stopping gaming, gradually increasing gaming time, inability to reduce gaming time, giving up other activities, developing dependence on gaming, etc.

Childhood game addiction is a serious social problem that involves multiple aspects, including mental health, physical health, and social functioning. Game addiction is a chronic mental and behavioral disorder characterized by the inability to control gaming behavior, which can have extensive negative psychological effects on adolescents. For example, a loss of self-awareness in real life, decreasing self-restraint, and inducing negative emotions such as anxiety, depression, and hostility[4]. Normal visual development begins at birth and continues throughout childhood. Adolescence is a critical period for the development of myopia, and prolonged gaming may lead to decreased vision and retinal lesions in teenagers[5]. Long-term gaming can also lead to health problems such as sleep deprivation, disrupted circadian rhythms, malnutrition, gastric ulcers, and obesity. In

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severe cases, prolonged sitting can cause lower limb venous thrombosis and even lead to sudden death due to pulmonary embolism[6]. In addition, if teenagers spend excessive time playing internet games, it will inevitably interfere with their daily lives and academic performance. Game addicts often devote significant time to gaming and frequently lack participation in social activities. Prolonged withdrawal from social interactions can reduce adolescents' sensitivity to nonverbal cues (such as facial expressions and gestures) in the social process, thereby impairing their ability to establish and maintain relationships in real life. This can result in increased family conflicts and the deterioration of important relationships[7].

Adolescent gaming addiction typically stems from the satisfaction of psychological needs, such as socialization, self-identity, and stress avoidance[8]. The real-time feedback and reward system in games reinforces this behavior, triggering the release of neurotransmitters such as dopamine, which creates a sense of pleasure and satisfaction. Due to the underdevelopment of brain regions associated with executive function, adolescents are more likely to transition from exploratory behavior (seeking pleasure and stimulation) to compulsive behavior (aimed at reducing the discomfort of not engaging in gaming) under the same addictive stimuli, making them more susceptible to addiction[9]. In addition, studies have found that worsening depressive symptoms significantly increase the risk of children developing gaming addiction. Although gaming itself does not directly cause depression, depressive emotions can subtly drive children toward game addiction[10]. This highlights the crucial role of mental health in preventing gaming addiction, particularly among children. Early detection and intervention of depressive symptoms May serve as an effective strategy to prevent children from becoming immersed in the gaming world

Our hypothesis is that gaming addiction can have adverse effects on vision, as well as on other aspects of physical and mental health. Therefore, this study focuses on the effects of game addiction on vision, ocular surface conditions and physical and mental health, as well as whether factors such as gender, age, region, and others influence the outcomes.

Materials and methods

Participant and inclusion procedure

The data collection period for this study spanned from July 2023 to January 2024, followed by data analysis conducted from March 2024 to June 2024. This study was carried out according to the Declaration of Helsinki[11], and received approval from the Ethics Committee of the First Affiliated Hospital of Nanchang University, with the ethical approval code 2,023,029. An online questionnaire survey was utilized for data collection, distributed via the Internet, and included six rating scales along with other related questions. Informed consent forms were signed by all guardians of the participants. The study aims to evaluate the daily gaming and sleep duration, myopia and ocular surface condition, physical and mental health status, and severity of online gaming disorders in adolescents. Its primary objective is to elucidate the relationship between game participation behavior and various health outcomes. A cross-sectional design was employed to collect and summarize data within a one-year period. Respondents were participants of the game 'Honor of Kings'. A random sampling procedure was employed to select a subset of samples with matched quantities for subsequent analysis. The selection process aimed to exclude extreme and abnormal data, ensure data representativeness, and particularly emphasized balancing key demographic variables (Fig. 1). Inclusion criteria for the game group: (1) IAT score greater than or equal to 20 points[12]; (2) Age range: 13–17; (3) No major physical diseases or mental disorders. Inclusion criteria for the non-game group : (1) IAT score less than 20 points; (2) Age range: 13–17; (3) No major physical diseases or mental disorders. The data of this study underwent a rigorous review process, and submissions that did not meet the specified game type and age range, or had unreasonable or incomplete completion times, were excluded from the analysis. The myopia assessment criterion was defined as a diopter of at least − 1.50 D in one eye.

Measures

Hospital anxiety and depression scale (HADS)

HADS is used to assess anxiety and depression in patients in general hospital settings. It consists of two subscales, HAS (anxiety) and HDS (depression), each containing seven items. Each item is scored on a four-point scale ranging from 0 to 3, where 0 indicates the absence of symptoms. A score of 1 suggests that the patient is aware of mild symptoms, which have little to no impact on the individual. A score of 2 indicates that the patient is aware of the symptom, which has a moderate impact on the subject. A score of 3 signifies that the symptoms are pronounced, and the frequency and intensity were very serious, which had a severe effect on the subjects. The scoring ranges for the anxiety and depression subscales are as follows: 0–7 points indicate no symptoms, 8–10 points suggest suspected anxiety or depression, and 11–21 points indicate definite anxiety or depression[13].

Van dream anxiety scale (VDAS)

VDAS consists of 17 items, with items 7 to 10 designed to collecting clinical information and therefore excluded from the final VDAS score. The remaining 12 items were scored using a 5-point Likert scale, ranging from 0 (never) to 4 (usually). These items assess various dimensions including nightmare frequency, sleep disturbances due to the anticipation of nightmares, dream recall frequency, difficulty returning to sleep after experiencing nightmares, etc. Each item is scored from 0 to 4. The total score for these symptoms ranges from 0 to 4, based on specific thresholds: 0–10 yields a score of 0, 11–20 scores 1, 21–30 scores 2, 31–40 scores 3, and 41–48 scores 4. By summing all 13 items, the final VDAS score ranges from 0 to 52[14].

The Short-From-36 health survey (SF-36)

SF-36 is used to evaluate health-related quality of life across eight distinct domains, including physical functioning, role limitations due to physical health, bodily pain, role limitations due to emotional problems, general health, vitality, social functioning and mental health. These eight domains can be grouped into two

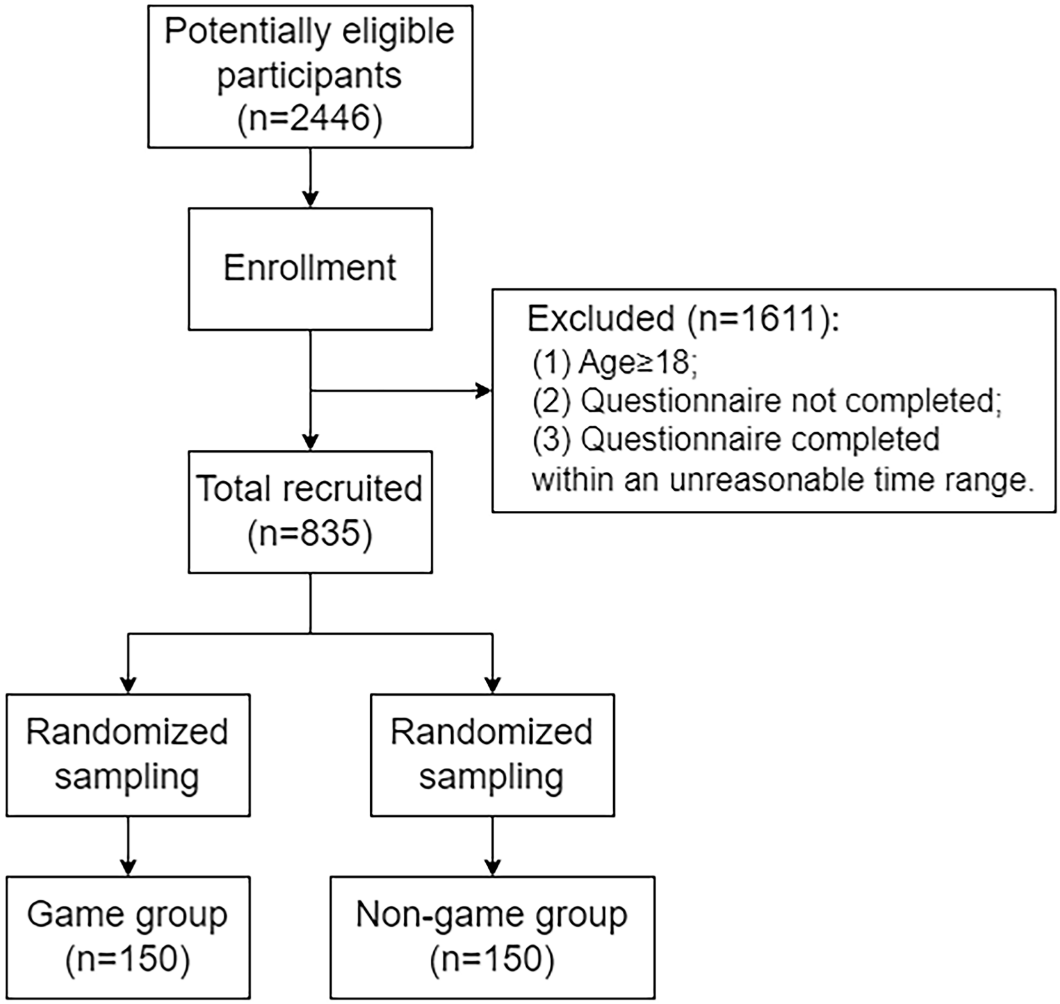

Fig. 1. Inclusion procedure.

summary measures: the Mental Component Summary (MCS) and the Physical Component Summary (PCS). The SF-36 is currently one of the most widely used standardized tools for quality of life internationally. The scoring method involves calculating the weighted sum of the scores for each item within a subscale to obtain a raw score, which is then transformed into a standardized score ranging from 0 to 100. A higher score on the scale indicates a better quality of life[15].

Ocular surface disease index (OSDI)
OSDI is a tool designed to assess the symptoms and quality of life of patients with ocular surface diseases. It was developed by the International Task Force on Dry Eye to evaluate and monitor ocular surface diseases, particularly dry eye syndrome. The OSDI questionnaire consists of 12 questions related to eye health and comfort, covering the patient 's symptoms, functional limitations, and the degree of distress caused by their eye condition. Each question provides specific response options, and patients are required to select the option that best matches their condition. The total score of the questionnaire ranges from 0 to 100, with higher scores indicating a more severe impact on symptoms and quality of life. Scores of 0–12 indicate normal eye health, 13–22 points indicate mild dry eye, 23–32 points indicate moderate dry eye, and 33–100 points indicate severe dry eye[16].

Internet addiction test (IAT)
IAT is used to assess the severity of internet addiction[17]. This scale consists of 20 items, each scored on a scale of 1 to 5 based on the level of agreement with the statement. A score of 1 indicates that the behavior never occurs, 2 indicates that it rarely occurs, 3 indicates that it occasionally occurs, 4 indicates that it often occurs, and 5 indicates that it always occurs. The total score ranges from 20 to 100 points. Participants with a total score of less than 50 points are classified as normal internet users. Higher total scores indicate more severe internet addiction, with scores of 80 points or above classified as severe internet addiction[18].

Internet gaming disorder Scale-20 (IGD-20)
IGD-20 evaluates the symptoms of online gaming disorder through six subscales, including salience, mood modification, tolerance, withdrawal symptoms, relapse, and conflict. Each subscale includes three items, except for the conflict subscale, which contains five items. Using a Likert scale, each item is scored from 1 (strongly disagree) to 5 (strongly agree). The total score ranges from 20 to 100. Participants with a score of 71 or higher are classified as having IGD[19].

Statistics
IBM SPSS Statistics (Version 27.0) and GraphPad Prism (Version 10.1.2) were utilized for data collection and analysis. SPSS was employed to conduct independent samples *t*-tests to compare the means of continuous variables between two groups. Chi-square test was used to assess differences in proportions across demographic categories. Respondents were classified based on their game duration, age and region, and Prism was used to perform linear regression analysis. Pearson correlation analysis was conducted to examine the relationships between gaming addiction and a series of psychological anxiety indices and health-related variables. Statistical significance was determined using a p-value threshold < 0.05, and the effect size was calculated to evaluate the strength of the observed associations. Prior to data analysis, the Shapiro–Wilk test, Kolmogorov–Smirnov test, and other statistical methods were applied to assess the normality of each variable. For data that did not meet the assumption of normality, logarithmic or square root transformations were applied based on the data characteristics. If the data still did not meet the normality assumption after transformation, nonparametric tests (Spearman correlation analysis and Mann–Whitney *U* test) were used as alternatives to methods relying on the normality assumption, ensuring the validity and reliability of the statistical analysis results.

Results
A total of 2446 volunteers participated in this questionnaire survey. After random sampling, 300 respondents were selected for analysis, with ages ranging from 13 to 17 years, most of whom were between 16 and 17 years old (32% in the non-game group and 29% in the game group). Males (90% in the non-game group and 89% in the game group) and northern Chinese (62% in the non-game group and 60% in the game group) constituted a significant proportion (Fig. 2). No significant differences were observed between the groups in terms of gender, age, or region. The sleep duration of the game group was significantly shorter ($t = 8.019$, $P < 0.0001$****). The mean ± standard deviation of the baseline characteristics of the study participants is presented in Table 1.

Under all six evaluation indicators, the mental and physical health status and ocular surface status of the game group exhibited a worse trend compared to the non-game group ($P < 0.0001$) (Fig. 3). Table 2 presents the mean ± standard deviation of the study variables and their respective subscales. Tables 3 and 4 reports the proportion of myopia in different age and game duration groups. The results indicate that both older age and longer game duration are associated with a higher proportion of myopia.

The HAS and HDS scores of the game group ($r = 0.4694$, $P < 0.0001$) and the non-game group ($r = 0.7507$, $P < 0.0001$) were strongly correlated (Fig. 4A, B). The MCS and PCS of the game group and the non-game group did not show any correlation (Fig. 4C, D).

The study found that game duration was strongly correlated with IAT ($r = 0.85$). There were strong correlation between game duration and HADS ($r = 0.71$), OSDI ($r = 0.68$) and IGD-20 ($r = 0.67$). In addition, OSDI was strongly correlated with IAT ($r = 0.62$). IAT was strongly correlated with HADS ($r = 0.67$) and IGD-20 ($r = 0.64$). All the above P values were less than 0.001 (Fig. 5).

Our analysis also revealed statistically significant differences in the scores of respondents with different demographic characteristics. Table 5 presents the comparative P-values of these health assessment indicators in different demographic groups. In addition to the significant differences between the game group and the non-game group, the table also highlights significant differences in scores between non-myopic and myopic individuals, as well as between males and females within the game group. Specifically, significant differences were observed in HADS ($t = 1.99$, $P < 0.05$), VDAS ($t = 2.175$, $P < 0.05$), OSDI ($t = 2.214$, $P < 0.05$), and IAT ($t = 3.723$, $P < 0.001$) between myopic and non-myopic players in the game group (Table 5).

In this regard, we conducted further analysis of the game group. The results showed that male gamers had significantly higher scores than female gamers in game duration ($t = 4.812$, $P < 0.0001$), sleep duration ($t = 4.342$, $P < 0.0001$), HADS ($t = 3.990$, $P < 0.001$), VDAS ($t = 3.801$, $P < 0.001$), IAT ($t = 5.800$, $P < 0.0001$), and IGD-20 ($t = 4.041$, $P < 0.0001$), while their SF-36 scores were significantly lower than those of female gamers ($t = 2.310$, $P < 0.05$) (Fig. 6A). Additionally, myopic gamers exhibited significantly higher game duration ($t = 3.491$, $P < 0.0001$) and IAT scores ($t = 3.723$, $P < 0.0001$) compared to non-myopic gamers (Fig. 6B). However, no significant differences were observed between different regions (Fig. 6C). We speculate that these findings may be attributed to the significantly longer game duration among male gamers compared to female gamers, as well as the longer game duration among myopic gamers compared to non-myopic gamers. This further supports the significant impact of gaming addiction on the assessed scores.

In addition, the IGD-20 scores of the game group showed significant correlations with HADS, VDAS, and OSDI among respondents who played more than five hours of online games per day, compared to the non-game group. The strongest correlations were observed among respondents who played more than 6 h of online games per day, where SF-36 (PCS) also demonstrated a significant correlation with IGD-20 (Table 6).

In the analysis of the game group, it was found that IGD-20 scores across all age groups were significantly correlated with other measures, including HAS, HDS, HADS, and OSDI (Table 7). It can be inferred that internet addiction has a substantial impact on the physical and mental health of adolescents across all age groups.

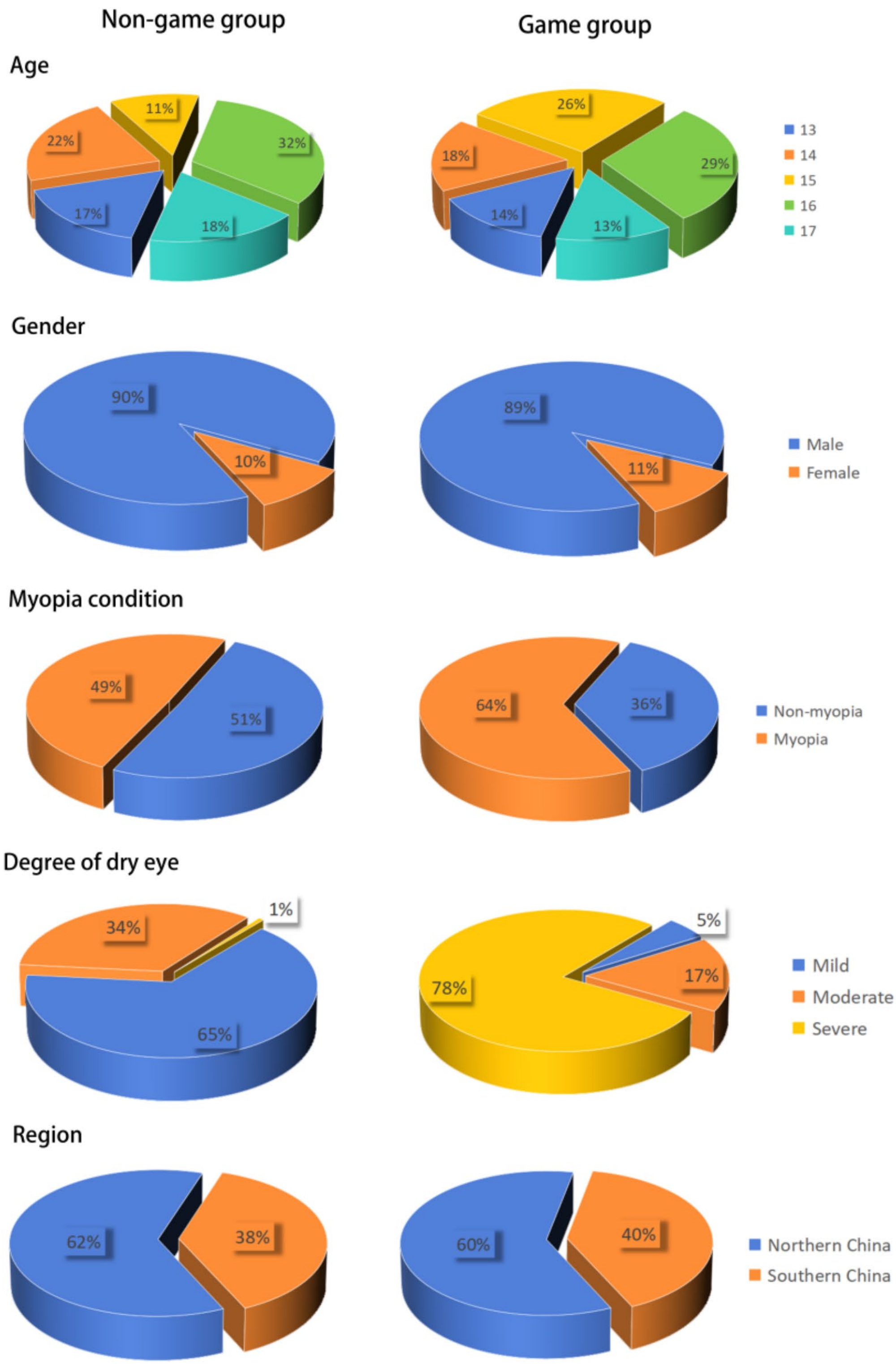

Fig. 2. The population proportion of enrolled participants. The population composition of participants by age, gender, myopia condition, degree of dry eye and region.

Discussion

Our study aims to illustrate the relationship between adolescent gaming addiction and myopia, ocular surface conditions, and overall health status, highlighting the multifaceted effects of excessive gaming among adolescents.

The results demonstrated that both older age and longer game duration were associated with a higher prevalence of myopia. Additionally, there were significant positive correlation between game duration ($r = 0.68$, $P < 0.001$), IAT ($r = 0.67$, $P < 0.001$) and OSDI scores. This suggests that excessive screen time and

	Non-gaming (SD) *n* = 150	Gaming (SD) *n* = 150	t	*P* value
Age	15.10 ± (1.38)	15.11 ± (1.24)	t = 0.171	0.865
Myopia condition				
Myopia	76	97	N/A	N/A
Non-myopia	74	53	N/A	N/A
Gender				
Male	134	134	N/A	N/A
Female	16	16	N/A	N/A
Region				
Northern China	59	63	N/A	N/A
Southern China	91	87	N/A	N/A
Sleeping duration (h)	8.01 ± (1.03)	7.11 ± (0.98)	t = 8.019	< 0.0001****

Table 1. Demographic characteristic of participants. ****$P < 0.0001$.

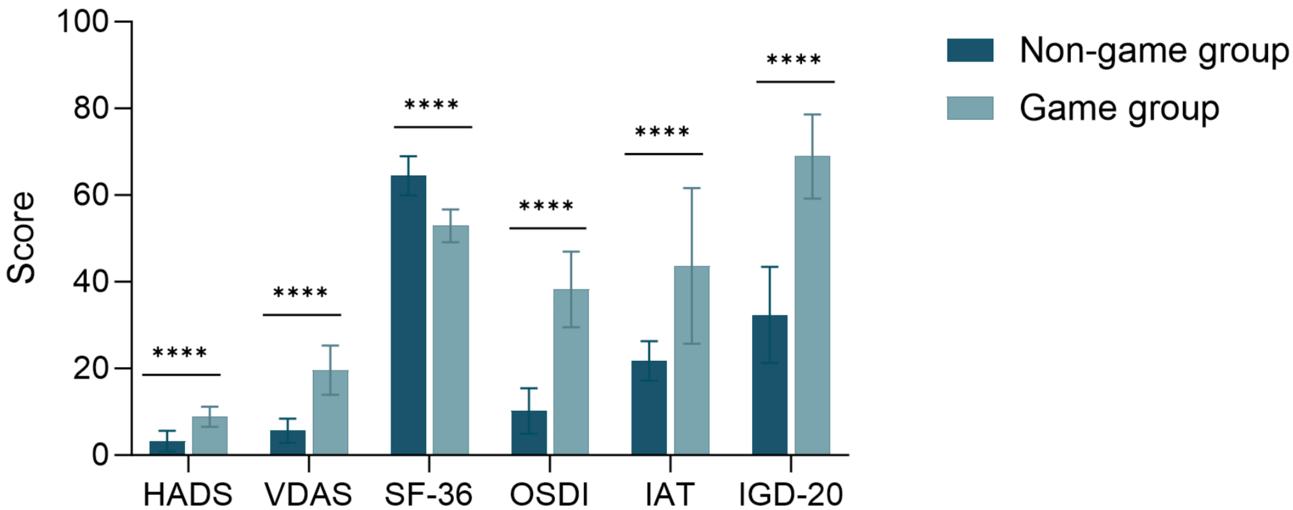

Fig. 3. Comparative analysis of differences in multiple health indicators between groups. This figure presents a comprehensive comparison of health indicators between the two groups, including Hospital Anxiety and Depression Scale (HADS), Van Dream Anxiety Scale (VDAS), 36-item Short-Form Health Survey (SF-36), Ocular Surface Disease Index (OSDI), Internet Addiction Test (IAT) and Internet Gaming Disorder Scale-20 (IGD-20). Significant mean differences between groups are symbolized by asterisks. ****$P < 0.0001$.

	Non-gaming (SD) *n* = 150	Gaming (SD) *n* = 150	t	*P* value
Health status				
HAS	1.63 ± (1.35)	4.18 ± (1.42)	17.56	< 0.0001****
HDS	1.65 ± (1.13)	4.43 ± (1.23)	20.35	< 0.0001****
HADS	3.31 ± (2.35)	8.68 ± (2.13)	21.12	< 0.0001****
VDAS	5.65 ± (2.7)	19.56 ± (5.43)	26.32	< 0.0001****
SF-36 (PCS)	65.05 ± (7.21)	61.32 ± (4.52)	5.11	< 0.0001****
SF-36 (MCS)	63.86 ± (4.25)	43.67 ± (5.13)	36.32	< 0.0001****
SF-36	515.73 ± (35.81)	423.35 ± (30.13)	23.98	< 0.0001****
Ocular status				
OSDI	10.25 ± (5.23)	38.13 ± (8.52)	35.12	< 0.0001****
Internet engagement				
IAT	21.75 ± (4.53)	43.23 ± (17.44)	14.35	< 0.0001****
IGD-20	32.32 ± (11.04)	68.65 ± (9.57)	30.56	< 0.0001****

Table 2. Multifaceted health status and online gaming disorder scores of enrolled participants. ****$P < 0.0001$.

Indicators characteristic (%)	Age (years)				
	13–14	14–15	15–16	16–17	17–18
Gaming myopia	31.8	39.3	58.5	70.8	99
Gaming non-myopia	68.2	61.7	41.5	29.2	1
Non-gaming myopia	3.8	8.6	38.9	71.1	79.3
Non-gaming non-myopia	96.2	91.4	61.1	28.9	20.7
Total myopia	17.8	23.9	48.7	75.9	84.2
Total non-myopia	82.2	76.1	51.3	24.1	15.8

Table 3. Proportion of myopia in different age.

Indicators characteristic (%)	Gaming duration (h)				
	0	1–2	3–4	5–6	>6
Myopia	48.8	50.5	60	72.7	76.5
Non-myopia	51.2	49.5	40	27.3	23.5

Table 4. Proportion of myopia in different gaming duration‘ groups.

digital engagement significantly contribute to ocular surface damage. Long-term gaming is a key factor in the development of dry eye syndrome[20]. According to relevant studies, prolonged exposure to electronic screens reduces blink frequency[21], accelerating tear film evaporation and leading to symptoms such as dryness, soreness, and eye fatigue. This effect is particularly pronounced during gaming, as players tend to focus intensely on the screen, further reducing blink frequency and exacerbating tear film instability.

In addition, the most significant correlation between IGD-20 and HADS was observed among gamers who played online games for more than five hours per day ($r = 0.723$, $P < 0.0001$), especially in gamers who play more than six hours a day ($r = 0.825$, $P < 0.0001$). This highlights a dose-dependent relationship between game duration and psychological distress. A significant correlation was also found between IGD-20 and SF-36 (PCS) among gamers who play more than six hours a day ($r = -0.534$, $P < 0.05$), further underscoring the detrimental effects of gaming addiction on health.

This study revealed a significant positive correlation between game duration and VDAS ($r = 0.53$, $P < 0.001$), which clarified the association between game addiction and increased dream-related anxiety. Game addicts who spend extended periods in competitive or high-pressure environments may overactivate cognitive and emotional processing during sleep[22], leading to disruptions in dream quality and the onset of anxiety-related sleep disorders. Long-term exposure to stressful gaming environments and sleep deprivation can contribute to an increase in sleep disorders[23], resulting in sleep fragmentation and interruptions in rapid eye movement (REM) sleep, both of which are critical for emotional regulation. This exacerbates anxiety associated with IGD[24]. Furthermore, sleep deprivation can impair prefrontal cortex function[25], weakening impulse control, increasing the susceptibility to addictive behaviors, and creating a vicious cycle.

Our results demonstrate that the IGD-20 scores of the gaming group across all age groups exhibit significant correlations with HADS and OSDI, indicating that gaming addiction has a substantial impact on the physical and mental health of adolescents of all ages. The frontal cortex, which is the last region of the human brain to fully develop, is responsible for executive functions such as impulse control, risk assessment, consequence evaluation, and decision-making[26]. Since the frontal cortex typically matures around the age of 20, adolescents and young adults often exhibit poorer self-control, greater impulsivity, and a stronger preference for risk-taking and stimulation compared to adults. Experimenting with addictive substances during adolescence is more likely to lead to substance use disorders than initiating such behaviors in adulthood[27]. In other words, addictive substances can induce behavioral and neurological abnormalities in adolescents similar to those observed in adults. However, due to the incomplete development of the adolescent brain, exposure to addictive substances during this period is more likely to result in addiction, and the associated neurological damage is significantly more severe than in adults.

In addition, research has found that game addiction is positively correlated with negative emotions (such as depression, anxiety, stress, and boredom) and affective disorders[28], while it is significantly negatively correlated with subjective well-being, life satisfaction, and positive emotions[29]. Negative emotions and affective disorders are strong predictors of addiction[30], a phenomenon that has been observed across various countries worldwide. Beyond the inherent appeal of games, the role of children's emotional states and emotional regulation abilities cannot be overlooked. Due to factors such as family relationships[31], parenting styles, and cultural influences[32], children who struggle to accurately identify and express their emotions often fail to understand others' feelings, establish healthy social relationships, and are more prone to experiencing negative emotions such as stress and anxiety. When family members lack meaningful communication, children are more likely to turn to games as a means of emotional regulation, which can easily lead to gaming addiction[33].

Our results demonstrated that male gamers had significantly higher scores than female gamers in gaming duration, HADS, VDAS, IAT, and IGD-20 ($P < 0.0001$), while their SF-36 scores were significantly lower than those of female gamers ($P < 0.0001$). Previous studies have shown that women are more influenced by sex

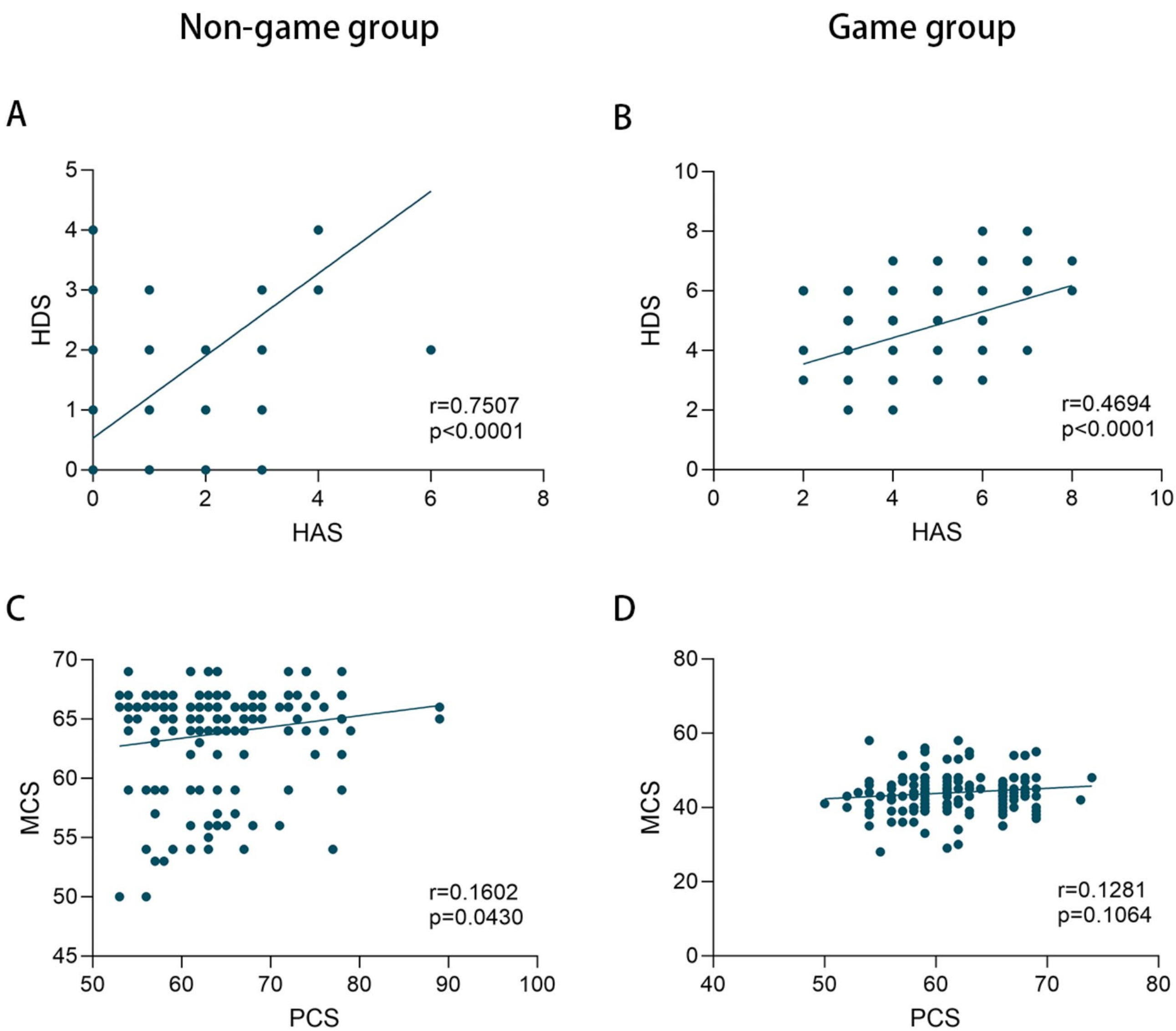

Fig. 4. Linear regression analysis assessing the association of HAS and HDS, PCS and MCS between groups. This figure presents the results of linear regression analyses investigating the relationships between the Hospital Anxiety Scale (HAS) and the Hospital Depression Scale (HDS), the Mental Component Summary (MCS) and the Physical Component Summary (PCS) between groups. The analyses were conducted separately for (**A**,**C**) non-game group and (**B**,**D**) game group.

hormones in addiction than men, and for women, estradiol increases susceptibility to addiction in women[34], primarily by regulating dopamine-mediated addiction processes. However, estradiol also exhibits a protective effect against addiction-related risk-taking behaviors, as evidenced by women engaging in fewer risky decision-making behaviors compared to men[35], This may be attributed to estradiol enhancing women's sensitivity to punishment, female addiction is significantly influenced by social alienation[36], whereas male addiction is more strongly associated with early maternal[37]. These behavioral differences stem from neurobiological distinctions between males and females. In addition, researchers believe that the psychological processes and corresponding mechanisms of impulsive decision-making in males and females may be different. Based on behavioral brain activation and symptom severity network analyses, a network relationship has been identified among time sensitivity, inferior frontal gyrus (IFG) activation under delayed decision-making conditions, and addiction severity in male IGD patients. In contrast, a network relationship exists among delayed discount rates, dorsolateral prefrontal cortex (dlPFC) activation under delayed conditions, and addiction severity in female IGD patients[38]. Studies have demonstrated that male adolescents are more susceptible to internet gaming disorder (IGD) than females[39]. Previous research has identified a link between gaming disorders in adolescent males and higher levels of maladaptive cognition[40]. For instance, teenage boys overrate the rewards of games and are reluctant to stop if they fail to complete certain game tasks. Other studies suggest that gender differences in brain structure and function may contribute to an increased risk of gaming addiction among male adolescents[41]. Magnetic resonance imaging (MRI) scans reveal that gaming elicits stronger desire-related activity in the male

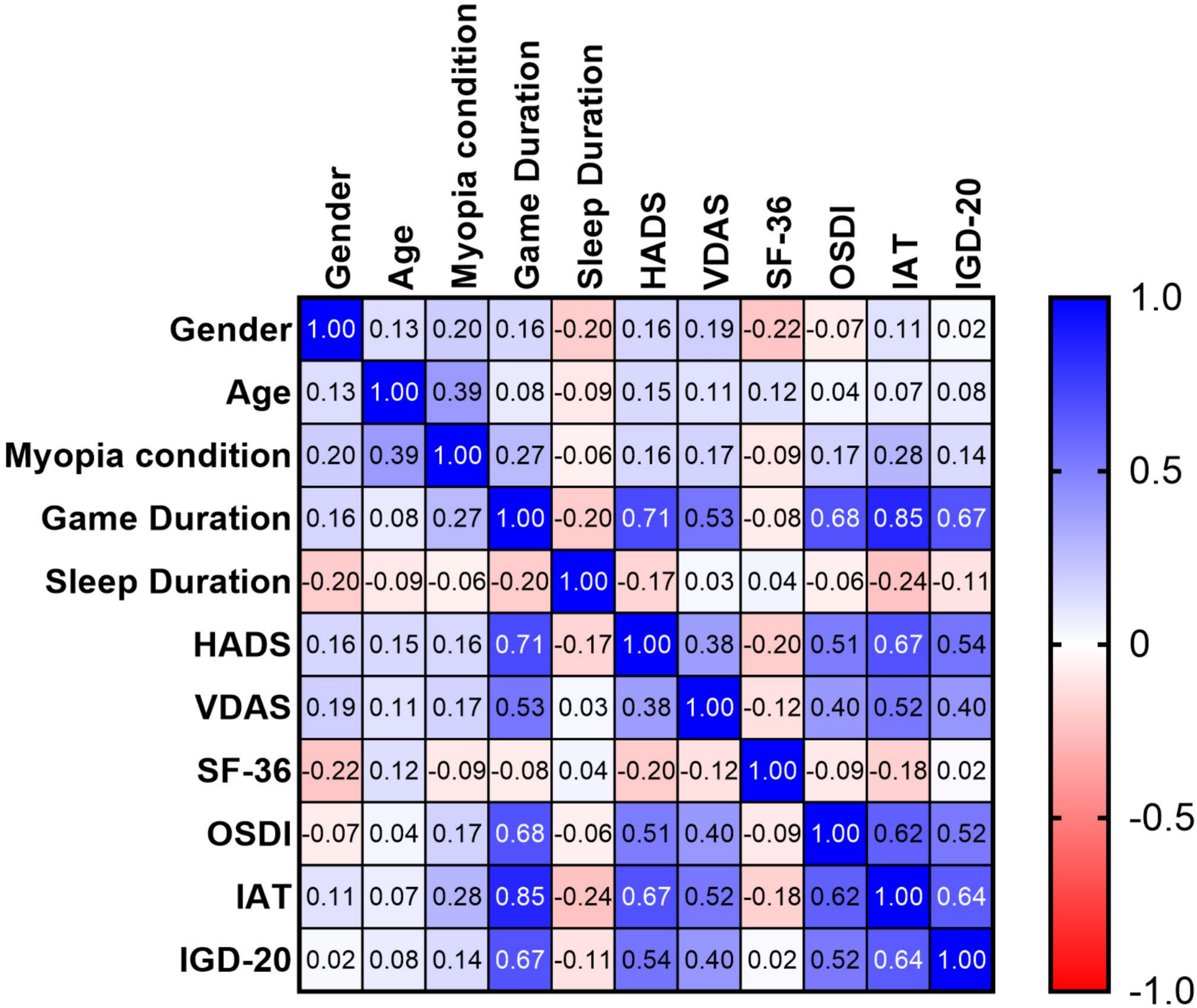

Fig. 5. Pearson correlation coefficient matrix of various indicators in the game group. This figure shows the results of Pearson correlation analysis between various indicators in the game group, investigating the relationship between gender, age, myopia condition, game duration, sleep duration, Hospital Anxiety and Depression Scale (HADS), Van Dream Anxiety Scale (VDAS), 36-item Short-Form Health Survey (SF-36), Ocular Surface Disease Index (OSDI), Internet Addiction Test (IAT) and Internet Gaming Disorder Scale-20 (IGD-20).

brain, consistent with findings in substance addiction and gambling addiction research. Magnetic resonance imaging scans showed that the game seemed to produce more desire-related activities in the male brain, which is consistent with research on substance addiction and gambling addiction. Additionally, MRI scans indicate that, compared to women, men are less sensitive to losses and more sensitive to rewards[42], which may explain why they tend to play games for a long time. Moreover, when faced with mental health challenges, teenage boys are more likely to resort to maladaptive coping mechanisms. Research has shown that men often experience greater shame when encountering mental health issues and adhere to societal expectations that men should not display vulnerability[43]. As a result, they are less inclined to discuss their feelings or seek professional help. Furthermore, boys generally exhibit lower abilities in identifying, managing, and preventing mental health problems[44]. Consequently, they may turn to behaviors such as gaming and substance abuse as a means of coping with emotional pain and distress.

The present study has several limitations. The cross-sectional design precludes the ability to establish causal relationships between online gaming and the observed physical, psychological, and ocular health outcomes. Although univariate linear regression analysis was employed, and previous analyses indicated weak correlations between the score results and other potential confounding factors ($r<0.3$), with hierarchical analysis demonstrating robust results, these findings still possess certain limitations. Additionally, the self-reported nature of the online questionnaire introduces subjectivity, which may affect the accuracy of reported behaviors and symptoms. Despite these limitations, this study has notable strengths, including a comprehensive assessment of

Indicators characteristic	HADS	VDAS	SF-36	OSDI	IAT	IGD-20
Myopia condition						
Non-myopia vs. myopia in non-gaming group	0.329 t = 0.979	0.461 t = 0.739	0.381 t = 0.879	**0.019*** **t = 2.374**	0.568 t = 0.572	0.310 t = 1.019
Non-myopia vs. myopia in gaming group	**0.048*** **t = 1.99**	**0.031*** **t = 2.175**	0.249 t = 1.156	**0.028*** **t = 2.214**	**0.0003***** **t = 3.723**	0.075 t = 1.794
Gender						
Non-gaming male vs. gaming male	**< 0.0001****** **t = 20.88**	**< 0.0001****** **t = 26.89**	**< 0.0001****** **t = 24.36**	**< 0.0001****** **t = 32.28**	**< 0.0001****** **t = 14.25**	**< 0.0001****** **t = 31.90**
Non-gaming female vs. gaming female	**< 0.0001****** **t = 5.635**	**< 0.0001****** **t = 8.576**	**< 0.0001****** **t = 7.761**	**< 0.0001****** **t = 14.84**	**< 0.0001****** **t = 5.078**	**< 0.0001****** **t = 6.225**
Gaming male vs. gaming female	**0.0470*** **t = 2.002**	**0.0176*** **t = 2.398**	**0.0043**** **t = 2.894**	0.3712 t = 0.897	0.1645 t = 1.396	0.7601 t = 0.306
Region						
Gaming northerner vs. gaming southerner	0.100 t = 1.656	0.734 t = 0.341	0.763 t = 0.302	0.461 t = 0.740	0.453 t = 0.752	0.775 t = 0.287

Table 5. The comparison of the multifaceted health and game addiction across demographic characteristic. *$P<0.05$; **$P<0.01$; ***$P<0.001$; ****$P<0.0001$.

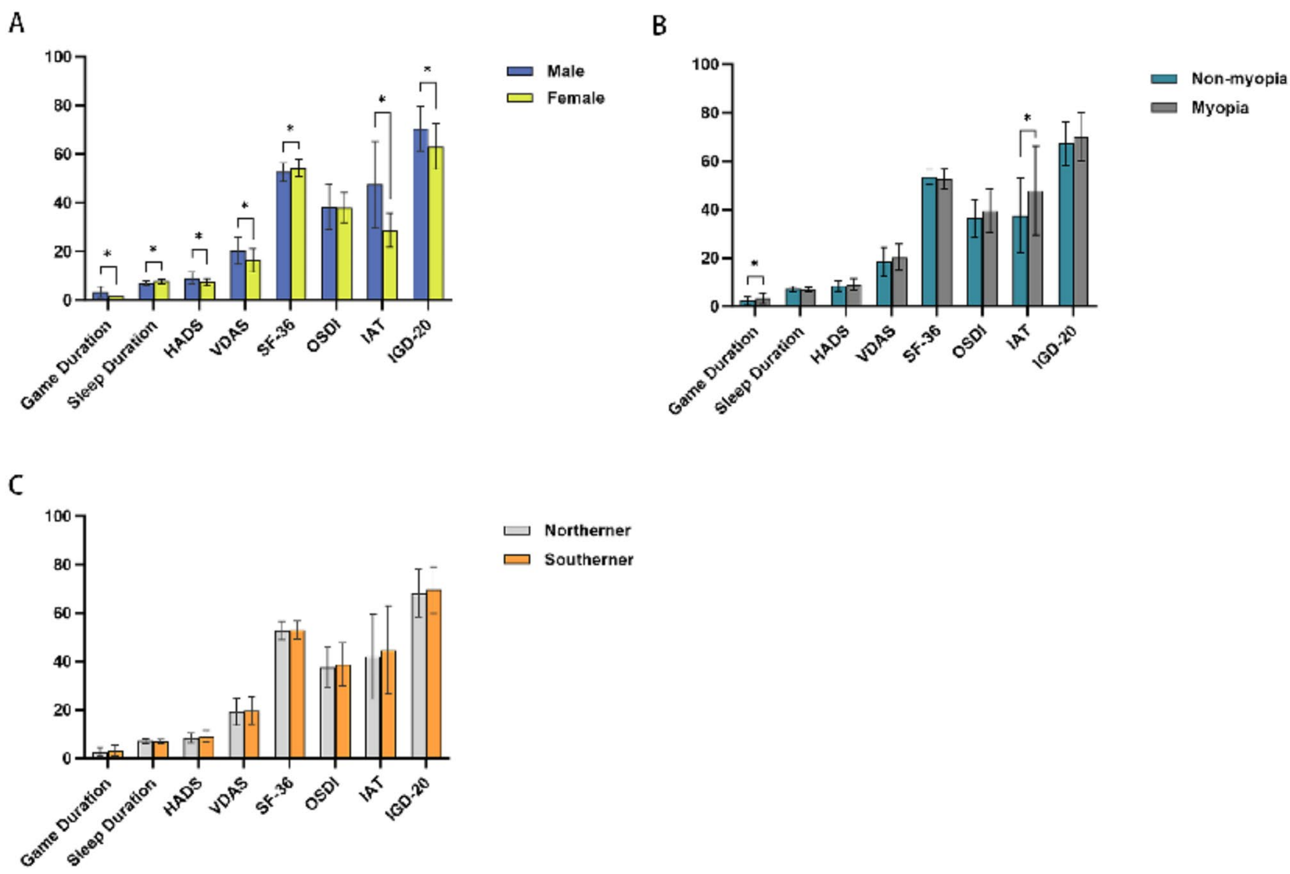

Fig. 6. Comparative analysis of demographic variations in multifaceted indicators. This figure presents a comprehensive comparison of indicators across different demographic groups, focusing on gender and regional characteristics. The analyses assess the impact of demographic variations on game duration, sleep duration, Hospital Anxiety and Depression Scale (HADS), Van Dream Anxiety Scale (VDAS), 36-item Short-Form Health Survey (SF-36), Ocular Surface Disease Index (OSDI), Internet Addiction Test (IAT) and Internet Gaming Disorder Scale-20 (IGD-20). (**A**) Comparative analysis of gender variations in multifaceted indicators. (**B**) Comparative analysis of myopia condition variations in multifaceted indicators. (**C**) Comparative analysis of region variations in multifaceted indicators. Significant mean differences between groups are symbolized by asterisks. *$P<0.0001$.

Gaming duration (h)	0	1–2	3–4	5–6	>6
Mental status					
HAS	0.153	**0.281****	**0.503***	**0.723*****	**0.859*****
HDS	0.074	0.145	0.311	**0.653****	**0.564***
HADS	0.123	**0.322****	0.335	**0.723*****	**0.825*****
VDAS	− 0.053	**0.123***	**0.502****	**0.688*****	**0.622****
SF-36 (PCS)	0.132	0.023	− 0.034	− 0.167	− **0.534***
SF-36 (MCS)	0.045	− 0.044	0.011	0.102	0.034
SF-36	0.134	− 0.035	− 0.008	− 0.055	0.423
Ocular status					
OSDI	**0.162***	**0.313****	**0.435***	**0.748*****	**0.925*****

Table 6. Correlation coefficient of IGD-20 with psychological and physical health scores, grouped by game duration. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Age (years)	13–14	14–15	15–16	16–17	17–18
Mental status					
HAS	**0.513***	**0.620*****	**0.399****	**0.565******	**0.581****
HDS	**0.448***	**0.491****	0.150	**0.337***	**0.783******
HADS	**0.538****	**0.651*****	**0.365***	**0.516*****	**0.754******
VDAS	0.303	**0.549****	**0.335***	**0.457****	0.276
PCS	0.270	− **0.405***	− 0.018	− 0.115	− 0.177
MCS	0.046	− 0.223	− 0.134	0.062	0.057
SF-36	0.260	− **0.406***	− 0.099	0.139	0.026
Ocular status					
OSDI	**0.621****	**0.472***	**0.485****	**0.528*****	**0.614****

Table 7. Correlation coefficient of IGD-20 with psychological and physical health scores in game group, grouped by age. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; ****$P < 0.0001$.

various health indicators across different population groups and the use of validated psychological measurement tools, which enhance the reliability of the results. Future research should adopt longitudinal designs, include more diverse populations, utilize multiple linear regression analyses, and integrate objective clinical evaluations to improve the validity and generalizability of the findings.

Conclusions

This study demonstrates a significant association between gaming addiction and a range of adverse physical, psychological, and ocular health outcomes, particularly among males. Excessive gaming duration can contribute to myopia and has a substantial negative impact on psychological health, physical health, and ocular surface conditions. The scores of male adolescent gamers are significantly lower than those of female gamers, which may be attributed to males' generally lower ability to identify, manage, and prevent mental health issues, as well as their typically longer gaming duration. This underscores the necessity of gender-specific intervention measures. A significant dose-response relationship was observed between gaming duration and symptom severity, highlighting the need for interventions targeting gaming time among adolescents. Additionally, the severity of internet gaming disorder is consistently associated with increased dream-related anxiety among all gamers, which further affects their sleep duration. Overall, our findings highlight the need for targeted interventions to mitigate the negative health effects associated with excessive play. These interventions should include promoting healthy gaming habits, raising awareness of eye care, and providing early mental health support, with a particular focus on male adolescent gamers. Future research should investigate the longitudinal effects of gaming on physical and mental health, as well as the efficacy of behavioral and cognitive interventions in reducing complications related to online gaming.

Data availability

The datasets used and/or analyzed during the present study are available from the corresponding author on reasonable request.

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Author contributions
Yi Shao and Yan Lou contributed to the study inception and design. Xiao-Yu Wang, Jin-Yu Hu, Qian-Ming Ge equally contributed to the literature search, analysis and writing of the manuscript. Other authors contributed to the study design and study supervision. All authors approved the final version of the manuscript.

Declarations

Competing interests
The authors declare no competing interests.

Ethical approval and consent to participate
The study methods and protocols were approved by the Medical Ethics Committee of the First Affiliated Hospital of Nanchang University (Nanchang, China) and followed the principles of the Declaration of Helsinki. The guardians of the adolescent participants have given informed consent for their participating in the questionnaire survey.

Additional information
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