

# Effects of prolonged continuous computer gaming on physical and ocular health and visual functions in young healthy individuals

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**Background and Objective.** Addiction to computer gaming has become a social problem in Korea and elsewhere, and it has been enlisted as a mental health disorder by the World Health Organization. Most studies related to computer use and vision have individually assessed physical and ocular symptoms and binocular vision. Accordingly, the present study comprehensively assessed subjective physical and ocular symptoms and functions related to binocular vision after prolonged continuous computer gaming. This study aimed to investigate the effects of prolonged continuous computer gaming on physical and ocular health and visual functions in young healthy individuals.

**Methods.** Fifty healthy college students (35 male/ 15 female), aged 19-35 years old, were enrolled in this study. The inclusion criteria were no binocular vision problems and no reported history of ocular disease. Participants played continuously for 4 h from 6:00 to 10:00 p.m. Physical and ocular symptoms and visual functions such as convergence, accommodation, phoria, and the blink rate were assessed before and after continuous computer gaming for 4 h.

**Results.** Continuous computer gaming for 4 h resulted in convergence and accommodation disturbances and increased physical and ocular discomfort. Near phoria showed a divergent shift, whereas distance phoria showed no change. Moreover, the accommodative and vergence facilities and blink rate were significantly decreased. All visual functions recovered to the baseline levels by the following morning.

**Discussion.** Our findings suggest that excessive and continuous computer gaming impairs visual functions and causes ocular and physical fatigue. Our findings further the understanding of the adverse effects of excessive computer use on physical and ocular health and highlight the need for measures such as ergonomically designed work spaces, visual exercises, and adequate rest periods for individuals performing computer-related tasks on a daily basis.

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## ABSTRACT

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# INTRODUCTION

The ability to visualize near objects clearly and accurately is necessary for individuals using computers and other digital screen devices on a daily basis. In today's generation, prolonged use of visual (or video) display terminals (VDTs) such as computers and smartphones has become very common and is one the main causes of ocular and physical discomfort (González-Pérez et al., 2014; Parihar et al., 2016). The majority of ocular and physical symptoms are associated with the effects of prolonged VDT usage on visual functions (Fenga et al., 2007; Tyrrell & Leibowitz, 1990; Yeow & Taylor, 1991). Computer vision syndrome (CVS), a condition associated with excessive computer use, is characterized by not only visual symptoms such as eyestrain, dry eyes, and blurred and double vision but also physical discomfort such as musculoskeletal shoulder disorders, neck pain, headache, and dizziness (Berqqvist et al., 1995; Hayes et al., 2007; Rosenfield, 2011). Even though problems related to computer use are well known, the rate of computer gaming in the general Korean population aged 10 to 65 years old was reported to increase from 67.9% in 2016 to 70.3% in 2017 by the Korean Games Users Survey Reports 2017 (The Korea Creative Content Agency, 2017).

Computer games have become a part of leisure activities in daily life, with young individuals spending excessive time indulging in such games (Wittek et al., 2016). The current most popular games require users to pay close attention to their VDTs, and the players show deep levels of emotional and physical addiction while gaming (Kim et al., 2016; Rikkers et al., 2016). Ubiquitous gaming cafes known as "PC bang" are very popular in Korea (Zastrow, 2017), where 24% children are reportedly diagnosed with internet gaming addiction requiring hospitalization (Ahn, 2017). Computer gaming addiction can cause health and mental issues (Griffiths, Kussa & King, 2012; Saquib et al., 2017). Furthermore, excessive computer use has been reported to cause problems associated with poor computer and visual ergonomics (Blais, 1999; Toomingas, 2014). A recent study showed that the neck and shoulder are the most commonly reported areas affected by excessive computer use (James et al., 2018). Other commonly reported symptoms include headache, eyestrain, double vision, dry eyes, and ocular fatigue (Akinbinu & Mashalla, 2014). Some studies (Qu et al., 2005; Yekta, Pickwell, & Jenkins, 1989) have also reported that near work on VDTs may cause not only ocular and physical symptoms but also transient changes in refraction, visual acuity, accommodation, and convergence. Tosha et al. (2009) examined the relationship between visual discomfort and the accommodation response in a college population with visual discomfort and found that increased visual discomfort is characterized by accommodative fatigue, with a higher lag of accommodation developing at a near viewing distance over time.

Furthermore, a study of over 1,173 Korean school-going children reported that the participants spent approximately 1.35 h on computer-based academics and 2.03 h on computer gaming during a normal day (Yang et al., 2014). Computer overuse has been deteriorating the visual environment year after year, and the "shutdown law" was recently introduced in Korea for the protection of youth from internet-based computer games (Kim et al., 2016; Sung, 2014).

Actually, most individuals addicted to computer games tend to play for prolonged hours without a break, and the effects of prolonged continuous viewing of VDTs at a near distance on physical and ocular health remain unclear. Moreover, most studies related to computer use and vision have individually evaluated physical and ocular symptoms and binocular vision. Therefore, we believe that a study focused on a comprehensive assessment of subjective physical and ocular symptoms and functions related to binocular vision after prolonged continuous computer use is necessary. Accordingly, the aim of this study was to investigate subjective physical and ocular symptoms and visual functions, as well as their interrelationships, after prolonged continuous computer gaming in young healthy individuals.

## METHODS

### Participants

This research complied with the tenets of the Declaration of Helsinki and was approved by the Institutional Review Board of Kangwon National University (KWNUIRB-2017-12-033). Informed consent was obtained from each participant.

Sample size was estimated based on the difference of computer-using time between a  $3.6 \pm 2.2$  hours per day and a  $2.4 \pm 1.6$  hours per day for internet-addicted and non-addicted Korea adolescents in the previous study, respectively (Yang et al., 2014). A sample size of 43 participants was required but fifty Korean healthy college students (age, 19-35 years, average age,  $22.5 \pm 3.4$  years; male:female, 35:15) were randomly enrolled as subjects for our study. The inclusion criteria were as follows: no near or distance vision problems; a corrected or uncorrected distance visual acuity of 20/25 (0.8) or better in each eye; normal stereopsis; and no reported history of ocular disease. Twenty-nine subjects (58%) wore spectacles, and their mean spherical equivalent power was  $-1.99 \pm 2.53$  diopters (D).

### Procedures

The subjects were asked to play a computer game (Diablo III, Blizzard Entertainment, USA) on a desktop computer screen (CX501N-KN/KOR with a 15-inch LCD monitor, Samsung, Korea) from a viewing distance of 50 cm under room illumination (approximately 50 lux). They played continuously for 4 h from 6:00 to 10:00 p.m. All subjects received a modified questionnaire<sup>26</sup> designed for assessing the effects of virtual reality viewing on monocular, binocular, and physical symptoms, as well as ophthalmological examinations for the assessment of visual functions, before and after the gaming session.

The questionnaire included 13 items pertaining to four physical and nine ocular symptoms. Each item was graded on a scale of 0 to 4 (0 = none, 1 = slight, 2 = moderate, 3 = severe, and 4 = very severe).

Visual functions were measured under habitual viewing conditions. Visual acuity was measured using visual charts (ACP-8, Topcon, Japan) and a phoropter (CV-3000, Topcon, Japan). The near point of convergence (NPC), which represents a visual function to obtain single vision, was measured by bringing an accommodative target to the nose and recording the point

time at which the subject could see double (Scheiman et al., 2003). The near point of accommodation (NPA), which represents a visual function for maintaining a clear image (Abraham et al., 2005), was measured using an accommodative convergence rule (GR50, Bernell, USA) while the subject attempted to read small letters (near visual acuity, 20/32). Phoria, which indicates latent misalignment of the eyes, was measured using Howell phoria cards (Wong, Fricke & Dinardo, 2002) (CDHP, Bernell, USA) at 3 m and 33 cm. Accommodative and vergence facilities (Weissberg, 2004; Gall, Wick & Bedell, 1998) were measured using a  $\pm 2.0$  D binocular flipper lens and a prism flipper ( $3 \Delta$  base-in +  $12 \Delta$  base-out;  $\Delta$ : prism diopter) at 40 cm. Finally, the blink rate was measured using a camcorder (NV-GS400, Panasonic, Japan).

### Statistical Analysis

All data were statistically analyzed using SPSS (ver. 18.0 for Windows, SPSS Inc., Chicago, IL, USA). Pearson's correlation analysis, paired t-tests, and repeated measures analysis of variance (ANOVA) were used for statistical analyses. The level of significance was set at  $p = 0.05$ . If significant differences were found, post hoc tests with Bonferroni corrections were used to identify the level of significance. Partial missing values in phoria and blink rate were excluded from descriptive statistics analyses.

## RESULTS

The mean scores for the four physical (nonocular) and nine ocular symptoms associated with computer game use are shown in Table 1. The mean overall scores for the physical and ocular discomfort domains increased from  $0.39 \pm 0.78$  and  $0.50 \pm 0.83$ , respectively, before the gaming session to  $1.61 \pm 1.24$  ( $t = 15.7$ ,  $p < 0.001$ ) and  $1.40 \pm 1.22$  ( $t = 17.44$ ,  $p < 0.001$ ), respectively, after the gaming session. The scores for all individual items also showed significant changes after the gaming session, and the mean difference was  $1.00 \pm 0.33$ . In the physical discomfort domain, the score for neck discomfort after the gaming session was the highest, followed by the scores for shoulder discomfort, headache, and back discomfort. In the ocular discomfort domain, the score for tired eyes was the highest ( $2.30 \pm 1.09$ ), followed by the scores for dry eyes, blurred vision, and eyestrain. The score for itchy eyes was the lowest ( $0.82 \pm 1.00$ ).

The effects of prolonged continuous computer gaming on visual functions are shown in Table 2. The mean NPC values showed significant changes immediately after and the morning after the gaming session ( $F = 47.83$ ,  $p < 0.001$ ). A post hoc Bonferroni multiple comparisons test indicated that NPC significantly increased immediately after the gaming session and recovered to the baseline level by morning. The mean NPA value also showed significant changes ( $F = 42.50$ ,  $p < 0.001$ ). A multiple comparisons test with Bonferroni correction showed that the NPA value after the gaming session was significantly different from the next-day value and the baseline value ( $p < 0.001$  for both); the next-day value and the baseline value showed no significant differences ( $p = 1.000$ ).

The accommodative facility (AF) and vergence facility (VF) significantly decreased after the gaming session. Both facilities recovered to baseline levels by the following morning.

The blink rate before the gaming session was 16.24 times per minute; this significantly decreased to 8.27 and 9.51 times per minute at 1 and 4h after the start of the game, respectively ( $F = 106.29$ ,  $p < 0.001$ ).

Horizontal phoria at distance showed no change after the gaming session ( $F = 1.67$ ,  $p = 0.193$ ), whereas horizontal phoria at near changed from  $-3.73 \pm 3.93$  before the gaming session to  $-5.75 \pm 4.85$  and  $-3.68 \pm 4.86$  immediately after and the day after the gaming session, respectively ( $F = 18.39$ ,  $p < 0.001$ ).

Pearson's correlation analysis showed a very weak negative correlation between itchy eyes and NPC after the gaming session ( $r = -0.294$ ,  $p = 0.039$ ) and a weak positive correlation between tired eyes and NPA ( $r = 0.361$ ,  $p = 0.01$ ) and between blurred vision and NPA ( $r = 0.298$ ,  $p = 0.036$ ) after the gaming session.

The changes in phoria during the computer gaming session are shown in [Fig. 1](#). Near phoria showed a divergent shift (exophoria) during the session (repeated measures ANOVA;  $F = 24.25$ ,  $p < 0.001$ ) and recovered to baseline levels by the following morning. Distance phoria showed no shift during the game (repeated measures ANOVA;  $F = 0.61$ ,  $p = 0.610$ ).

## DISCUSSION

In the present study, we found that prolonged continuous computer use for gaming resulted in both physical and ocular discomfort as well as impaired visual functions. In particular, the neck and shoulder, which remain in the same posture while playing, were affected. The major visual symptom was ocular fatigue (tired eyes), followed by dryness and blurred vision. These findings are consistent with those of other studies ([Hayes et al., 2007](#); [Klussmann et al., 2008](#)) reporting a high prevalence of neck and shoulder symptoms, ocular fatigue, and blurred vision after excessive computer use. The findings of a 13-item questionnaire used in our study revealed higher scores for physical symptoms than for ocular symptoms after 4 continuous hours of gaming, although tired eyes was associated with the highest score. This can be explained by the fact that high accommodation and convergence values are required for maintaining a clear vision at small distances from VDTs, and these values need to be maintained for the entire gaming duration. This invariably results in ocular fatigue. On the other hand, the body posture can be frequently changed.

We also found changes in visual functions after continuous computer gaming for 4 h in the present study. NPC, a visual function used to achieve single vision during near-distance work, showed a significant increase after the gaming session and recovered to the baseline level the next day. [Qu et al. \(2005\)](#) found that NPC was significantly increased after short-term VDT use. However, [Yeow and Taylor \(1991\)](#) found that NPC decreased with an increase in age, with no significant difference between VDT and non-VDT users. [Hamed, David, and Marzieh \(2013\)](#) reported that the evaluation of NPC helped in the differentiation of symptomatic and asymptomatic subjects, and that the average NPC value for break point was 11.7 cm. While NPC is a measurement of how close one can bring a fixation target to the nose while maintaining fusion, NPA is used to assess the amplitude of accommodation. The accommodation and



convergence disturbances observed after the gaming session in the present study can be attributed to intra- and extra ocular muscle fatigue resulting from the prolonged continuous computer gaming.

Accommodative and vergence facilities permit the ability to sustain clear and single binocular vision during near-distance work. A healthy individual's accommodative facility should be binocularly clear within  $10.0 \pm 5$  cpm (Scheiman & Wick, 2002). In the present study, the value showed a significant change from 12.68 to 15.54 cpm. The vergence facility for single binocular vision also showed a significant change from 15.02 to 17.70 cpm; the norm is 15 cpm (Weissberg, 2004). These changes may be associated with symptoms such as ocular fatigue, eyestrain, and blurred vision, although NPC and NPA showed significant changes within normal values. Both accommodative and vergence facilities recovered by the next morning.

Pickwell, Jenkins, and Yekta (1987) reported that 30 min of reading in inadequate illumination or from an abnormally close distance resulted in an increase in phoria with the development of ocular symptoms. However, Yekta et al. (1989) found that near-dissociated phoria increased from 4.70  $\Delta$  exophoria to 5.20  $\Delta$  exophoria after 30 min of reading and decreased to 4.87  $\Delta$  exophoria after 30 min of relaxation, with no accompanying symptoms. The results of the present study also showed that near phoria (dissociated phoria) increased from 3.73  $\Delta$  exophoria to 5.75  $\Delta$  exophoria with the development of symptoms after continuous computer gaming for 4 h, and it subsequently recovered to 3.68  $\Delta$  exophoria by the following morning. This result is consistent with those of other studies (Yekta et al., 1989; Tsubota & Nakamori, 1993) showing an exophoric shift in phoria due to near-distance tasks, with no significant change in distance phoria over time. Collectively, these findings suggest that near phoria for binocular vision changes to exophoria under the effect of visual stress caused by factors such as inappropriate illumination, abnormal working distance, and prolonged working hours.

The mean blinking rate at rest reportedly varies from 12 to 19 blinks per minute (Karson et al., 1981). Tsubota and Nakamori (1993) observed 22 blinks per minute under relaxed conditions and seven blinks per minute during VDT work. Patel et al. (1991) reported 18.4 blinks per minute before a computer task and 3.6 blinks per minute during the computer task. We found that the number of blinks per minute significantly decreased from 16.24 before the gaming session to 8.27 after 1 h of gaming and 9.51 after 4 h of continuous gaming. However, we do not know whether the decreased blink rate induces ocular fatigue, or vice versa. However, the blink rate may be an effective index for assessing visual fatigue during VDT tasks. Intentional blinking during VDT tasks is required to minimize visual fatigue. Therefore, we highly recommend blink training to increase the blinking rate during prolonged computer use.

Pearson's correlation analysis showed that ocular fatigue and blurred vision were weakly related to NPA, whereas itchiness was weakly related to NPC. These subjective symptoms may be provoked by the accommodation and convergence disturbances induced during prolonged computer gaming.

This study is limited by the small study sample that included patients with healthy eyes without binocular vision problems so that there were minimum confounding variables. A larger

sample of patients with binocular disorders is necessary for extensive estimation of the effects of prolonged continuous computer gaming. Nevertheless, our findings offer valuable insights and provide the first direct evidence of changes in physical and ocular health and visual functions after prolonged continuous computer gaming.

## CONCLUSIONS

In summary, the findings clearly indicate that changes in visual functions evoke ocular symptoms after prolonged continuous computer gaming, which also induces physical symptoms. Although these changes are usually temporary, visual fatigue caused by long-term VDT use may tend to accumulate over time. Accordingly, these changes could be potential risk factors for irreversible physical and visual disturbances associated with computer overuse. Users may need rest to alleviate fatigue due to computer use. Moreover, individuals should be advised regarding their working hours. Therefore, it seems reasonable that all individuals should be advised to take breaks and periodically gaze into the distance to minimize accommodation and vergence disturbances; longer rest periods will result in lesser physical and ocular fatigue. In addition, the use of prisms, near addition, and vision training can relieve ocular discomfort and fatigue associated with prolonged VDT use. Finally, ergonomically designed work spaces are desirable to minimize physical discomfort after long VDT tasks.

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 363

# **Table 1**(on next page)

Changes in physical and ocular symptom scores after continuous computer gaming for 4 h.

1

Symptoms	Score, mean $\pm$ SD		Significance
	Before gaming	After gaming	
Physical discomfort	0.39 $\pm$ 0.78	1.61 $\pm$ 1.24	t = 15.7, p < 0.001
Shoulder	0.48 $\pm$ 0.81	1.88 $\pm$ 1.19	t = 8.80, p < 0.001
Neck	0.44 $\pm$ 0.81	1.92 $\pm$ 1.21	t = 9.78, p < 0.001
Back	0.20 $\pm$ 0.53	1.16 $\pm$ 1.15	t = 6.60, p < 0.001
Headache	0.42 $\pm$ 0.91	1.46 $\pm$ 1.30	t = 6.76, p < 0.001
Ocular discomfort	0.50 $\pm$ 0.83	1.40 $\pm$ 1.22	t = 17.44, p < 0.001
Red eyes	0.48 $\pm$ 0.81	1.38 $\pm$ 1.09	t = 7.18, p < 0.001
Eyestrain	0.44 $\pm$ 0.79	1.58 $\pm$ 1.03	t = 8.32, p < 0.001
Itchy eyes	0.44 $\pm$ 0.79	0.82 $\pm$ 1.00	t = 2.57, p = 0.013
Tired eyes	0.94 $\pm$ 0.98	2.30 $\pm$ 1.09	t = 8.73, p < 0.001
Dry eyes	0.64 $\pm$ 1.01	1.64 $\pm$ 1.34	t = 6.86, p < 0.001
Tearful eyes	0.34 $\pm$ 0.80	0.88 $\pm$ 1.14	t = 3.62, p < 0.001
Irritated eyes	0.34 $\pm$ 0.66	0.96 $\pm$ 1.12	t = 3.73, p < 0.001
Blurred vision	0.46 $\pm$ 0.73	1.60 $\pm$ 1.20	t = 7.28, p < 0.001
Aching eyes	0.40 $\pm$ 0.76	1.40 $\pm$ 1.29	t = 6.29, p < 0.001

2 Symptoms were scored on a scale from 0 (none) to 4 (very severe).

3 SD: standard deviation

4 The p-values were determined using paired t-tests.

5

# **Table 2**(on next page)

Changes in binocular function after continuous computer gaming for 4 h.



1

Binocular function	Before gaming	After gaming	Following morning	Significance
NPC (cm)	7.23 ± 1.64	8.77 ± 1.60	7.36 ± 1.29	F = 47.83, p < 0.001
NPA (cm)	7.79 ± 1.44	9.11 ± 1.93	7.78 ± 1.49	F = 42.50, p < 0.001
Phoria at distance (Δ)	-0.76 ± 1.71	-0.83 ± 2.25	-0.62 ± 1.69	F = 1.67, p = 0.193
Phoria at near (Δ)	-3.73 ± 3.93	-5.75 ± 4.85	-3.68 ± 4.86	F = 18.39, p < 0.001
Accommodative facility (cpm)	14.42 ± 3.20	12.68 ± 3.98	15.54 ± 2.95	F = 30.08, p < 0.001
Vergence facility (cpm)	16.94 ± 3.16	15.02 ± 3.67	17.70 ± 3.41	F = 38.97, p < 0.001
Blink rate (per minute)	16.24 ± 5.14	(8.27 ± 5.40) <sup>†</sup>	(9.51 ± 5.28) <sup>‡</sup>	F = 106.29, p < 0.001

2 Data are expressed as means ± standard deviations.

3 NPC: near point of convergence, NPA: near point of accommodation, Δ: prism diopter, cpm: cycles per minute. <sup>†</sup>Blink rate  
4 after 1 h, <sup>‡</sup>Blink rate after 4 h.

5 The p-values were determined using repeated measures analysis of variance. Negative and positive values for phoria  
6 represent exophoria and esophoria (horizontal), respectively. Missing data are 15 persons for phoria and 10 persons for  
7 blink rate.

8

# **Figure 1**(on next page)

Changes in phoria during a continuous 4-h computer gaming session.

The error bars represent standard deviations. Negative values denote exophoria and positive values denote esophoria (horizontal).

Phoria (prism diopter)

