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ORIGINAL RESEARCH

The Effect of Four Hours of Continuous Personal Computer (PC) Gaming on the Development of Dry Eye Symptoms in College Students

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Purpose: The purpose of this study was to evaluate if a short period of playing video games on a personal computer (PC) causes changes in measurements of dry eye disease (DED).

Patients and Methods: We recruited 41 Quinnipiac University students (ages 18–23 years, mean age 19.66±1.09 years; 9 females, 32 males), with eligibility criteria being 18+ years old, identifying as "gamers" without previous history of eye surgery, steroid use, autoimmune disorders, or history of or previous treatment for dry eye. Each student was administered DED-related assessments before/after four hours of continuous PC gaming: 1) Standardized Patient Evaluation of Eye Dryness (SPEED) and Ocular Surface Disease Index (OSDI) questionnaires, 2) Snellen visual acuity test, 3) tear osmolarity point-of-care assay, 4) matrix metalloproteinase-9 (MMP-9) inflammation point-of-care assay, and 5) an unanesthetized Schirmer test of tear production. Students were limited to 500 cc of water during the four hour period.

Results: Following gaming, the mean SPEED scores increased significantly ($p<0.001$, Wilcoxon signed-rank test), as did the frequency and severity of soreness/irritation and eye fatigue. Tear osmolarity decreased and tear production increased in the right eye. Other metrics (OSDI, Snellen, and MMP-9) did not change significantly.

Conclusion: As little as four hours of continuous PC gaming with limited hydration results in an increase in self-reported measures of DED symptoms. These prospective findings corroborate the epidemiological link between gaming and DED symptoms and highlight the need for long-term studies.

Keywords: dry eye disease, screen use, matrix metalloproteinase-9, tear osmolarity

Introduction

Dry eye disease (DED) is a chronic, multifactorial condition characterized by the loss of homeostasis of the tear film.[1,2] For people with DED, tear film instability often results in discomfort, including itching, burning, stinging, or a foreign body sensation, and may additionally result in visual impairment, including photophobia and blurred vision. DED may also be accompanied by concomitant inflammation, epitheliopathy, and neurosensory abnormalities.[2] Globally, dry eye has been estimated to impact 5–50% of the adult population,[3] with a meta-analysis reporting a global prevalence of 49.5%.[4]

While DED is most prevalent in older adults,[1,5,6] there has been a noted increase in prevalence among younger individuals in recent years, with studies reporting rates of symptomatic DED in high school and college students ranging from 23%[7] to as high as 90%.[8] These high rates have been linked to a variety of lifestyle and environmental factors, including increased use of smartphones, computers, tablets, and gaming systems.[6–11] Prolonged use of digital screens reduces blink rate and increases incomplete blinks,[6–8,11–15] leading to increased tear evaporation and tear osmolarity and symptoms of DED. Unfortunately, even one to two hours per day of screen use can be associated with DED, indicating that the average younger individual in the United States is at risk.

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Gamers represent a population that is particularly at risk for DED because of excessive screen exposure. During gaming, blink rates halve those during conversation and are maintained throughout the gaming session,[10] vastly increasing the possibility of tear evaporation. Despite a strong link between gaming and DED,[6,10,13,14,16] few studies have prospectively investigated whether gaming conditions, which include exposure to a screen, the cognitive demands of gaming, and limited hydration, can produce clinically significant results on typical DED diagnostic screens.

In this prospective cohort study, we subjected college-aged individuals to personal computer (PC) gaming conditions (screen use and limited hydration) for four hours and evaluated DED symptoms before/after. The prospective findings reported herein support the epidemiological link between gaming and DED in younger people and highlight the need for individuals who game to limit screen time or proactively treat DED symptoms.

Material and Methods

Subject Recruitment & Inclusion/Exclusion Criteria

College-aged students from Quinnipiac University were recruited through announcements from the Quinnipiac University Esports Club and Game Design and Development classes. Inclusion criteria were as follows: 18+ years of age, identifying as "gamers" without previous history of eye surgery, steroid use, autoimmune disorders, or history of or previous treatment for dry eye. Students were excluded if they demonstrated dry eye symptoms at baseline. All the students enrolled in the study provided informed consent before the start of the study.

Study Design

Students were evaluated before and after four hours of gaming to determine the impact of gaming on DED symptoms. Students were given the following DED tests: 1) Standardized Patient Evaluation of Eye Dryness (SPEED) and Ocular Surface Disease Index (OSDI), 2) Snellen visual acuity, 3) Tear osmolarity, 4) matrix metalloproteinase 9 (MMP-9) inflammation, and 5) an unanesthetized Schirmer test. SPEED and OSDI questionnaires were administered first to ensure that screenings in contact with the eyes did not influence questionnaire measurements, and the Schirmer test was performed last to ensure that the withdrawal of aqueous tears did not influence osmolarity or MMP-9 measurements. This testing order was repeated before and after the gaming. Before the study, students were not permitted to use eye drops but were encouraged to eat and drink fluids at the request of the IRB.

Gaming Environment

Study participants were placed in the Quinnipiac University Gaming Lab to play video games on a PC (Alienware Aurora R12 with NVIDIA RTX 3080 GPU) continuously over a four hour period, with a mandatory five minute break every hour. Students were limited to a maximum fluid intake of 500 cc during gaming to mimic the gaming conditions. The students sat one to two feet away from the monitors and could play any game or switch between games. Temperature and humidity within the room were measured every hour during the five-minute breaks and remained relatively constant (temperature 22.92 ± 1.11 °C; humidity 48.5 ± 3.19%). The students underwent dry eye assessments immediately before and after they were subjected to these conditions.

Dry Eye Evaluations

Standardized Patient Evaluation of Eye Dryness (SPEED)

SPEED is a standardized questionnaire that evaluates the presence, frequency, and severity of DED symptoms including dryness, grittiness, scratchiness, soreness or irritation, burning or watering, and eye fatigue. The results were scored from 0–28: 0–4, mild dry eye symptoms; 5–7, moderate dry eye symptoms; and 8+, severe dry eye symptoms. The students completed a questionnaire on paper.[17]

Ocular Surface Disease Index (OSDI)

The OSDI measures the frequency of DED symptoms and evaluates how symptoms impact specific tasks and are influenced by environmental conditions. The results were scored from 0–100: 0–12 normal, 13–22 indicates mild dry eye

symptoms, 23–32 indicates moderate dry eye symptoms, and 33–100 indicates severe dry eye symptoms.[18] The students completed a questionnaire on paper.

Snellen Visual Acuity Test

DED may influence visual acuity. Thus, the students were given a standard Snellen Chart visual acuity test, which did not depart from standard clinical practice.

Tear Osmolarity

Increased tear osmolarity is a marker for tear film instability and DED. Tear osmolarity was measured using a TearLab Osmolarity System (TearLab, Escondido, CA, USA). Briefly, a trained ophthalmologist/ophthalmic technician collected a tear sample from each eye using the pen and test card of the system and docked it into the system to obtain the osmolarity measurements. Osmolarity, indicative of DED, is typically above 307 mOsm/L, whereas normal osmolarity is below this threshold.[17]

Matrix Metalloproteinase-9 (MMP-9) Levels

Inflammation of the cornea, conjunctiva, and meibomian and lacrimal glands is often accompanied by DED. A proxy for inflammation is the level of MMP-9.[2] The MMP-9 levels were measured using the InflammaDry MMP-9 Test (Quidel, San Diego, CA, USA). A trained ophthalmologist or ophthalmic technician dabbed both eyes of each participant with the sample collector, saturating the sampling fleece by dabbing multiple locations along the palpebral conjunctiva. The sample collector was snapped onto the test cassette and the assembly was placed in a buffer vial for 20 seconds before being removed. After 10 minutes of development, test results (either + or −) were obtained. A "+" result is indicative of MMP-9 levels >40 ng/mL and DED-associated inflammation, while a "-" result is indicative of MMP-9 levels <40 ng/mL and no inflammation. Each eye was separately tested.

Unanesthetized Schirmer Test

A decrease in aqueous tear production can be a measure of aqueous-deficiency DED. Aqueous tear production was measured using the unanesthetized Schirmer test. Briefly, a trained ophthalmologist/ophthalmic technician dried the lower eyelid, placed a filter paper strip on the lower eyelid, and removed the paper after five minutes to evaluate the amount of wetting by measuring the distance tears traveled down the paper away from the eye. Normal tear production ranges from 10–30 mm. Less than 10 mm is abnormal and a possible indication of dry eyes, while less than five mm indicates severely dry eyes.

Statistical Analysis

Averages for each data parameter before and after gaming were calculated for the left and right eyes independently (excluding SPEED and OSDI scores) and for males and females independently and grouped. The influence of the gaming intervention on SPEED and OSDI scores was evaluated using the Wilcoxon signed-rank test, and a paired *t*-test was used to evaluate Snellen visual acuity, tear osmolarity, and Schirmer results. For MMP-9 measurements, the number of eyes with MMP-9 levels that switched from normal to elevated, from elevated to normal, or stayed elevated or normal was calculated. McNemar's test was used to evaluate whether the likelihood of eyes switching from normal to elevated or from elevated to normal was equal. A power analysis was performed based on a similar experimental study by Chidi-Egboka et al (2022) that found a standardized difference of d=0.32 in the primary outcome tear film measure between pre- and post-gaming exposure.[10] All statistical analyses were performed using the RStudio software.

Results

Participants

A total of 41 students aged 18–23 years (mean age 19.66±1.09 years) were recruited, with nine being female (mean age 19.78±0.97 years) and 32 being male (mean age 19.63±1.13 years).

Questionnaires — SPEED & OSDI

The SPEED and OSDI questionnaires are tools commonly used to evaluate eye dryness and demonstrate high positive predictive power for DED.[18,19] Thus, students were asked to complete the SPEED and OSDI questionnaires immediately before and after four hours of continuous PC gaming to evaluate whether the intervention influenced self-reported symptomatology (Table 1 and Table 2). Following gaming, the average overall SPEED score increased 1.84-fold, and this change was statistically significant. Similarly, the average frequency of soreness/irritation was significantly increased by more than three times, and the corresponding average severity of soreness/irritation was significantly increased and by 2.5x. Similarly, the frequency of average eye fatigue nearly doubled, and the corresponding average severity increased by a factor of 2.4; these increases were statistically significant. Conversely, the average frequency and severity of dryness/grittiness/scratchiness and burning/watering symptoms did not change significantly despite means demonstrating a minor

Table 1 Overall and Component SPEED Scores Before (Baseline) and After the Gaming Period (Final)

Measure	Baseline-Female	Final-Female	P-value-Female	Baseline-Male	Final-Male	P-value-Male	Baseline-Overall	Final-Overall	P-value-Overall
Overall SPEED	2.11±3.95	7±6.61	**0.022**	2.94±3.32	4.53±4.38	**0.013**	2.76±3.43	5.07±4.97	**<0.001**
Soreness/Irritation Frequency	0.22±0.44	0.78±0.97	0.089	0.19±0.47	0.59±0.84	**0.012**	0.2±0.46	0.63±0.86	**0.001**
Soreness/Irritation Severity	0.11±0.33	1.11±1.36	0.057	0.25±0.51	0.41±0.56	0.145	0.22±0.47	0.56±0.84	**0.008**
Eye Fatigue Frequency	0.67±1.12	1.22±0.97	0.168	0.53±0.80	0.97±0.97	**0.0351**	0.56±0.87	1.02±0.96	**0.008**
Eye Fatigue Severity	0.44±0.73	1.56±1.33	**0.0335**	0.47±0.67	0.97±1.03	**0.0144**	0.46±0.67	1.1±1.11	**<0.001**
Dryness/Grittiness/Scratchiness Frequency	0.22±0.44	0.33±0.50	0.766	0.34±0.55	0.56±0.80	0.115	0.32±0.52	0.51±0.75	0.10
Dryness/Grittiness/Scratchiness Severity	0.11±0.33	0.56±0.73	0.174	0.41±0.80	0.44±0.67	0.902	0.34±0.73	0.46±0.67	0.33
Burning/Watering Frequency	0.22±0.67	0.67±1.12	0.174	0.44±0.62	0.34±0.70	0.393	0.39±0.63	0.41±0.81	0.80
Burning/Watering Severity	0.11±0.33	0.78±1.39	0.181	0.31±0.59	0.25±0.57	0.588	0.27±0.55	0.37±0.83	0.50

Note: "SPEED" refers to Standard Patient Evaluation of Eye Dryness. "Overall" refers to females and males combined. Bolded items indicate statistically significant results comparing baseline and final values at $p<0.05$.

Table 2 Overall and Component OSDI Scores Before (Baseline) and After the Gaming Period (Final)

Measure	Baseline-Female	Final-Female	P-value-Female	Baseline-Male	Final-Male	P-value-Male	Baseline-Overall	Final-Overall	P-value-Overall
Overall OSDI	5.55±9.32	8.98±9.24	0.1221	9.31±9.38	7.71±8.34	0.3468	8.49±9.39	7.99±8.44	0.8775
Sensitive to Light	0.56±0.73	0.11±0.33	0.1736	0.81±0.82	0.72±1.02	0.5621	0.76±0.80	0.59±0.95	0.2147
Gritty	0.0±0.0	0.11±0.33	1	0.13±0.34	0.22±0.49	0.3741	0.10±0.30	0.20±0.46	0.2402
Painful or Sore	0.22±0.44	1.22±1.39	0.0708	0.28±0.58	0.53±0.84	**0.0498**	0.27±0.55	0.68±1.01	**0.0064**
Blurred Vision	0.44±1.33	0.78±1.30	0.1489	0.56±1.08	0.44±0.91	0.4584	0.54±1.12	0.51±1.00	0.9412
Poor Vision	0.56±1.33	0.78±1.30	0.3458	0.75±1.24	0.25±0.88	**0.0133**	0.71±1.25	0.37±0.99	**0.0297**

Note: "OSDI" refers to Ocular Surface Disease Index. "Overall" refers to females and males combined. Bolded items indicate statistically significant results comparing baseline and final values at $p<0.05$.

increase. When SPEED scores were analyzed according to sex, some findings differed. The mean SPEED score increased significantly after gaming in males and females. The soreness/irritation frequency was significantly increased in males but was not statistically different in females. The severity of soreness/irritation was not significantly different between the males and females. For eye fatigue, the frequency was statistically higher after gaming in males, but not in females, and the severity was statistically increased in both males and females. None of the other metrics (dryness/grittiness/scratchiness and burning/watering frequency and severity) before and after gaming were statistically different between males and females. Each comparison was performed using the Wilcoxon signed-rank test.

The average OSDI score did not change significantly after gaming. Likewise, when analyzed by sex, the average OSDI score did not change significantly in females or males. The only statistically significant changes were in the average painful/sore and poor vision rating parts of the OSDI score, which increased and decreased, respectively. When analyzed by sex, the same two ratings were statistically significant for males (increased and decreased, respectively), but not for females (Table 2). Each comparison was performed using the Wilcoxon signed-rank test.

Snellen Visual Acuity Test

DED may influence visual acuity through its impact on tear film instability and the subsequent pathophysiology (eg, corneal or conjunctival epitheliopathy). To assess the influence of gaming on visual acuity, students were subjected to a standard Snellen Visual Acuity test before and after gaming. No measures of visual acuity after gaming, whether right eye distance visual acuity, left eye distance visual acuity, right eye near visual acuity, or left eye near visual acuity, were found to be statistically different from baseline, consistent with the analysis of the overall subject sample and separation by sex (Table 3). Each comparison was evaluated using the paired *t*-test.

Tear Osmolarity

Changes in tear osmolarity are key markers of DED; patients diagnosed with DED typically have higher tear osmolarity. Tear osmolarity was evaluated before and after four hours of continuous gaming to determine whether a brief gaming period was sufficient to induce changes in osmolarity (Table 4). The tear osmolarity in the right eye decreased significantly, but the changes were not significant across all participants. When tear osmolarity scores were analyzed

Table 3 Distance and Near Visual Acuity by Eye Before (Baseline) and After Gaming (Final)

Measure	Baseline-Female (feet)	Final-Female (feet)	P-value-Female	Baseline-Male (feet)	Final-Male (feet)	P-value-Male	Baseline-Overall (feet)	Final-Overall (feet)	P-value-Overall
Right Eye Distance Visual Acuity	20.00±0.00	20.00±0.00	1	27.19±31.77	22.34±7.40	0.312	25.61±28.13	21.83±6.59	0.310
Left Eye Distance Visual Acuity	20.56±1.67	20.56±1.67	1	34.38±67.32	27.97±31.90	0.316	31.34±59.55	26.34±28.26	0.315
Right Eye Near Visual Acuity	24.44±3.91	24.44±3.91	1	24.38±6.06	24.06±5.15	0.690	24.39±5.61	24.15±4.86	0.710
Left Eye Near Visual Acuity	23.89±4.17	26.11±4.17	0.272	27.50±14.26	31.56±31.66	0.213	26.71±12.78	30.37±28.03	0.154

Note: "Overall" refers to females and males combined.

Table 4 Tear Osmolarity by Eye Before (Baseline) and After (Final) Gaming

Measure	Baseline-Female (mOsm/L)	Final-Female (mOsm/L)	P-value-Female	Baseline-Male (mOsm/L)	Final-Male (mOsm/L)	P-value-Male	Baseline-Overall (mOsm/L)	Final-Overall (mOsm/L)	P-value-Overall
Right Eye Tear Osmolarity	297.22±13.89	296.11±17.30	0.790	300.84±11.44	291.19±11.74	**<0.001**	300.05±11.93	292.27±13.07	**<0.001**
Left Eye Tear Osmolarity	295.89±16.50	304.89±17.50	0.078	297.84±13.11	295.44±21.46	0.575	297.41±13.72	297.51±20.83	0.977

Note: "Overall" refers to females and males combined. Bolded items indicate statistically significant results comparing baseline and final values at $p<0.05$.

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by sex, tear osmolarity in the right eye was still found to significantly decrease after gaming in males but not in females. Each comparison was evaluated using the paired *t*-test.

MMP-9 Levels

Often, DED is accompanied by concomitant inflammation, including release of MMP-9 found in nearly 40% of patients with confirmed DED.[19] To evaluate if gaming resulted in inflammation, students were subjected to a commercially available point-of-care MMP-9 assay before/after the gaming intervention.[20] This assay indicates if MMP-9 levels are high (+) or low (−) with respect to a cutoff of 40 ng/mL. Most left and right eyes at baseline were (+) and most of these remained (+) after gaming, though some changed to (-) (Table 5). Likewise, of those that were originally (-), most remained (-) after gaming though some changed to (+) (Table 5). McNemar's test produced a chi-squared test statistic with a p-value of 0.2109, indicating that the number of eyes in gamers that changed from (−) MMP-9 levels pre-gaming to (+) post-gaming was not statistically different from eyes that changed from (+) pre-gaming to (−) post-gaming.

Unanesthetized Schirmer Eye Test

In aqueous-deficient DED, the lacrimal glands produce insufficient tears to keep the eyes moist. To evaluate if four hours of continuous gaming influenced aqueous tear production, the students were subjected to the Schirmer Eye Test 5 min before and after the gaming period to measure tear production (Table 6). The average tear production in the right eye significantly increased after gaming but did not change in the left eye. When analyzed by sex, tear production was found to significantly increase after gaming in the male right eye; however, all other comparisons were not statistically significant.

Power Analysis

Assuming a similarly low effect size as that in the Chidi-Egboka experimental study using a two-sided paired *t*-test with an alpha level of 0.05, a sample of 41 participants, and a correlation r = 0.7, a power of 52% was calculated to detect a significant difference.

Table 5 MMP-9 Test Results Before (Baseline) and After (Final) Gaming

	Eyes (+) at Baseline			Eyes (-) at Baseline		
Eye	**Baseline (+)**	**Final (+)**	**Final (-)**	**Baseline (-)**	**Final (+)**	**Final (-)**
Left	32	25	7	9	4	5
Right	28	20	8	13	4	9

Note: "Baseline" refers to before gaming, "Final" refers to after gaming. (+) refers to MMP-9 levels > 40 ng/mL, whereas (-) refers to MMP-9 levels <= 40 ng/mL.

Table 6 Unanesthetized Schirmer's Test Results Before (Baseline) and After (Final) Gaming

Measure	Baseline-Female (mm)	Final-Female (mm)	P-value-Female	Baseline-Male (mm)	Final-Male (mm)	P-value-Male	Baseline-Overall (mm)	Final-Overall (mm)	P-value-Overall
Right Eye Schirmer's Test	21.22±10.20	23.67±11.49	0.445	23.26±12.84	25.42±11.83	**0.043**	22.80±12.20	25.03±11.63	**0.036**
Left Eye Schirmer's Test	28.33±10.42	24.78±13.13	0.144	25.90±12.21	24.06±11.65	0.306	26.45±11.75	24.23±11.82	0.132

Note: "Overall" refers to females and males combined. Bolded items indicate statistically significant results comparing baseline and final values at p<0.05.

Discussion

DED is a multifactorial condition whose canonical symptoms include ocular pain or discomfort and a decrease in tear film stability.[2] Beyond these symptoms, DED is often accompanied by concomitant inflammation, epitheliopathy, and neurosensory abnormalities.[2] In recent years, epidemiological studies have revealed a strong link between exposure to digital screens—computers and smartphones alike—and DED diagnosis or DED symptoms.[10,13,14] However, little work has prospectively investigated if screen exposure is sufficient to cause DED symptoms. To address this gap, we prospectively evaluated if a four-hour period of continuous PC gaming with limited hydration in a cohort of 41 college-aged gamers influenced DED symptoms.

When evaluating patients with dry eye, a key element of a clinical diagnosis is the presence of ocular pain or discomfort as measured by standardized patient questionnaires.[21] Here, we evaluated subjects using SPEED and OSDI questionnaires and found that gaming led to an increase in the overall SPEED score and an increase in the frequency and severity of soreness/irritation and eye fatigue, but did not change dryness/itchiness/scratchiness or burning/watering. When analyzed by sex, the average SPEED score changed significantly; however, certain SPEED components were no longer significant despite exhibiting a nearly two-fold increase. These results were particularly evident in female participants, indicating a loss of significance that could be explained by the relatively small sample size (n=9 females) and large standard deviations. Unlike the overall SPEED score, gaming did not result in significant changes in OSDI scores. However, this was expected, as the OSDI is largely composed of questions assessing how eye symptoms impact engagement with the subject's environment (eg, driving at night), and could not change because individuals were evaluated immediately before and after gaming. The lack of changes in dryness/itchiness/scratchiness or burning/watering in SPEED and other eye symptoms in OSDI (light sensitivity, blurred vision, grittiness) may be a result of these outcomes reflecting pathophysiological changes associated with persistent DED that would simply not be induced by such a short screen exposure. However, some individuals experienced an increase in the frequency and severity of these symptoms, indicating that gaming can alter these metrics. Interestingly, the SPEED and OSDI results both before and after gaming fell at the lower end of the reported values for those who identified as gamers, possibly because individuals were young or had a limited gaming history; however, we did not collect information on gaming habits. Nonetheless, these results demonstrate that as little as 4 hours of continuous gaming with limited hydration results in a statistically significant increase in the frequency and severity of specific self-reported measures of eye discomfort. These findings reflect the measures observed in patients at risk of DED and in the early stages of DED.[22]

In addition to self-reports of ocular discomfort, reduced tear film stability is a hallmark of DED. This may result from either decreased tear production by the lacrimal glands (ie, aqueous-deficient DED) or meibomian gland dysfunction, which influences the presence of oils in the tear film and hastens tear film evaporation (ie, hyperevaporative DED).[6,23] Tear film instability may yield tear hyperosmolarity. Although we did not directly evaluate tear film stability or meibomian gland function, we evaluated tear production and tear osmolarity. Gaming was found to increase tear production (Schirmer test) and decrease tear osmolarity in the right eye in both the overall sample and in males; no changes were observed in females. Interestingly, no significant changes were found in the left eye, which reflects clinical findings indicating that DED often develops asymmetrically across the eyes.[2,21] Rather than observing increased osmolarity and decreased tear production as seen in DED, we found the opposite, possibly indicative of individuals compensating for decreased blinking known to occur during gaming[10,12,13] and reflecting the short-term nature of the gaming exposure, which may not have been long enough to induce pathophysiological decreases in tear production. The influence of gaming on these measures must be further investigated, as epidemiological studies indicate that screen exposure is poorly correlated with tear production or osmolarity.[6,8,14] Changes in tear film stability can also influence visual performance,[2,24] so we measured visual acuity via a routine Snellen evaluation. However, Snellen results did not change after gaming. These results indicate that the present gaming conditions may have influenced tear production and tear osmolarity but did not influence simple visual acuity.

Individuals with DED often experience concomitant inflammation of the corneal surface, conjunctiva, and/or the supporting glands. In the past decade, MMP-9 has been recognized as an inflammatory biomarker in DED.[2] Elevated levels of MMP-9 are associated with a disruption of the corneal epithelial barrier; elevated MMP-9 breaks down tight junctions between corneal cells that makes the eye more prone to dryness and irritation.[2] Here, we measured MMP-9 levels before/

after gaming using a point-of-care assay and found there was not a statistically significant difference between the number of eyes that changed from having "normal" MMP-9 levels (ie, 3–40 ng/mL) to elevated MMP-9 levels (ie, >40 ng/mL) vs eyes that switched from elevated to normal. This result demonstrated that a short gaming period is equally likely to result in an increase or decrease in inflammation. Rather than conclusively reflecting the influence of gaming on DED-associated eye inflammation, we speculate that this result may reflect participants' inflammation levels fluctuating around the threshold of the point-of-care assay and additionally reflect the relatively short duration of gaming, which may be insufficient to result in increased inflammation, even when there is a lack of hydration or use of artificial tears.

Our study has several limitations. Namely, we did not directly measure tear film stability using fluorescein dye and a tear break-up time (TBUT) assay, which is typically the gold standard tool to evaluate the presence of DED.[6,14,24] However, implementing this approach for such a short-term gaming session would unnecessarily complicate measurements and burden the participants. If used before gaming, fluorescein dye would result in blurred vision that would require at least a few hours to return to normal, and its side effects could artificially elevate DED symptoms that confound the interpretation of the study's results. Furthermore, the use of the dye would drastically increase the time required by participants, require more hands-on time from ophthalmologists to evaluate the TBUT, and require gaming systems and ophthalmologic tools to be in proximity or otherwise require students to be shuttled. In future long-term studies, we are interested in evaluating TBUT with fluorescein dye to understand more definitively whether gaming directly influences tear film stability. Similarly, we did not measure blink rate, which is generally reduced following gaming and is thought to be the mechanism by which DED develops in individuals exposed to screens.[10–13] Similar to TBUT, we did not have appropriate tools available to us to measure blink rate in the gaming lab. Lastly, we acknowledge that this study was underpowered and thus it is difficult to detect if a true effect exists in our sample. Nonetheless, our results still demonstrated that gaming exposure is correlated with self-reported measures of dry eye, tear production, and tear osmolarity. Whether these findings correlate with blink rate will be determined in future studies that assess a greater number of individuals.

Moving forward, we hope to extend this study to include a larger sample, including a control group, and a more thorough screening for DED that includes measurements of tear film instability (TBUT with fluorescein dye) and functional visual acuity measurement[2,6,24] to better understand how gaming influences these measures. Importantly, we may consider recruiting individuals without gaming experience, as the gaming history of individuals in this study may have influenced the results (albeit unlikely because most individuals did not demonstrate clinically significant DED results before the gaming period). Nevertheless, this study is one of the first to directly evaluate whether short-term exposure to a controlled gaming environment influences clinically significant measures of DED that are typically used to evaluate the presence of the condition.

Conclusion

Our data show that a short, 4-hour period of continuous PC gaming with limited hydration can lead to an increase in self-reported measures of DED symptoms, such as soreness/irritation and eye fatigue, and can affect tear production and osmolarity. These prospective findings support the epidemiological link that has been demonstrated between gaming and DED symptoms and highlight the need for long-term studies that involve more thorough screening of DED using standard techniques to measure tear film stability and blink rate, which are phenomena that contribute to the pathogenesis of dry eye symptoms.

Abbreviations

DED, dry eye disease; SPEED, Standardized Patient Evaluation of Eye Dryness; OSDI, Ocular Surface Disease Index; MMP-9, matrix metalloproteinase-9.

Data Sharing Statement

All data used in the preparation of this manuscript is available from the corresponding author upon request.

Ethics Approval and Informed Consent

This study was approved by the Quinnipiac University Institutional Review Board. This study complies with the Declaration of Helsinki.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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