EXTENDED SCREEN TIME AND DRY EYE IN YOUTH

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ABSTRACT

PURPOSE

Extended screen time amongst youth is a pervasive global phenomenon, with wide-ranging implications for health and quality of life. Dry eye disease is increasingly reported as emerging in paediatric populations and is associated with modified blinking behaviour during extended screen time. This study sought to evaluate spontaneous blink rates, dry eye symptomology and screen use habits of young extended screen time users.

METHODS

Attendees of a gaming convention in Auckland, NZ, completed a self-directed iPad-based survey on personal screen use habits and ocular symptoms using the 5-item Dry Eye Questionnaire (DEQ-5) and the Symptom Assessment in Dry Eye (SANDE). Blink rate was covertly and concomitantly recorded using the front-facing iPad camera and quantified by automated software. A validated, self-assessment blink test was administered as a proxy for tear film stability measurements.

RESULTS

A total of 456 respondents (mean age ± SD: 24 ± 10 years, range: 13 – 75, 38% female) reported an average weekly screen time of 43.7 ± 24.4 hours. DEQ-5 and SANDE scores were 10 ± 3 and 34 ± 19; 90% of respondents qualified as symptomatic for dry eye disease (DEQ-5 ≥ 6). Blink test results suggested a tear film stability < 10 seconds in 24% of cases. Poorer symptomology correlated with increased screen use, elevated blink rates and reduced proxy tear film stability (r=0.15 to 0.22, all p<0.01).

CONCLUSION

Extended screen time in a young population was associated with blinking behaviour and symptomology consistent with patients with dry eye. Implementing routine clinical screening, educational interventions, and developing official guidance on safe screen use may help prevent an accelerated degradation of ocular surface health and quality of life in young people.

Keywords: dry eye disease, ocular surface, children, lifestyle, screen time, digital display use, video display terminal, incomplete blinking

INTRODUCTION

A screen-based lifestyle is today's norm, whether in professional, educational or leisure settings, for adults and children alike. Mounting evidence indicates that extended screen time during childhood is associated with negative impacts on a wide range of health, wellbeing, and educational outcomes. [1] Amplified by the COVID-19 pandemic, [1–3] these trends have sparked calls for national and international guidelines on limiting screen use in youth, [2,4,5] with suggestions that current usage levels may far exceed these recommended limits. [6]

Ocular discomfort ranks among the most common effects of extended screen time. Up to 90% of adult computer users report experiencing dry eye symptoms. [7–10] In children, myopic progression [3] and ocular surface changes have been associated with extended screen time. [11–13] Rates of dry eye disease (DED) in otherwise healthy paediatric populations range from 6.6% to 44%. [13–22] The mechanism by which extended screen time contributes to DED is believed to be through modified blink dynamics, which in turn facilitate the onset and progression of ocular surface changes, [23] some of which may be irreversible. [12] DED weighs a heavy burden on patient quality of life, productivity, learning, and the economy. [7,24,25] The pervasiveness of extended screen time from an early age and the unavoidable role of screens in work settings may therefore predispose youth to a higher prevalence and severity of DED [12,26–28] and an earlier, more rapid decline of quality of life. [8,24]

Reduced spontaneous blink rates and lid closure completeness during extended screen time affect tear film stability, aqueous evaporation, osmolarity, the accumulation of inflammatory mediators and other factors that facilitate the onset and progression of DED. [29,30] However, spontaneous blink dynamics remain poorly understood, owing to their multifactorial variability and elusive neural control. [31] Crucially, the assessment of spontaneous blink rates depends on measurement conditions, a fact that has been frequently ignored previously. [32,33] Methodological approaches often rely on video recordings and subjective evaluation, rendering (double) masking problematic, while experimental locations are limited to laboratories or clinical, unfamiliar settings that can heighten subject awareness, or stimulate changes in blink dynamics, potentially skewing results. [31] More non-invasive means of evaluating spontaneous blinking may help garner a better understanding of the emerging phenomenon of paediatric dry eye disease in the context of extended screen time.

Young gamers offer an opportunity for studying the effects of long-term extended screen time. This study thus sought to evaluate the association between extended screen time, blinking dynamics and symptoms and signs of dry eye disease in a young cohort of gamers, using automated, covert blink detection software.

METHODS

This study was conducted at a gaming convention (Armageddon 2019, Auckland, New Zealand), where attendees were invited to self-complete a survey of their demographics, screen use and gaming habits, dry eye symptoms and quality of life on an Apple iPad (Cupertino, California, USA). A custom-designed survey software enabled covert automated blink tracking analysis. All participants provided informed consent before study participation, and ethics approval for conducting this study was obtained from the University of Auckland Human Participants Ethics Committee (UAHPEC 023894).

Screen use and gaming were reported as estimated numbers of hours and days during a typical week and weekend and averages computed, expressed as total weekly screen time and total weekly gaming time for analysis. Laptops/computers, smartphones, tablets, virtual reality sets (but not TV) were collectively considered “screens”, and screen time included time spent gaming.

Dry eye symptomology was assessed using the Dry Eye Questionnaire (DEQ-5) and the Symptom Assessment In Dry Eye (SANDE) questionnaires. [34,35] The DEQ-5 consists of five questions assessing eye discomfort, dryness, and watering during a typical day in the past month by frequency (“never” to “constantly”) and intensity (“not at all intense” to “very intense”). A score greater or equal to 6 (out of 22) is considered positive. [36,37] The SANDE incorporates two questions on frequency (“rarely” to “all of the time”) and severity (“very mild” to “very severe”) of dry eye, presented as 0-100 horizontal visual-analogue scales. The total score is then the square root of the product of the frequency and severity scores. Self-perceived quality of life in daily task performance and quality of life for vision-related tasks were assessed using a visual-analogue scale from 0 (no impact) to 100 (maximal impact).

During the survey, spontaneous blink rates were covertly recorded using the front-facing iPad camera. Blink dynamics were analysed with custom software built on a commercially available machine learning algorithm (Google Firebase ML Kit). The algorithm processed, segmented, and classified the facial and ocular features in the image, providing a percentage probability for blink detection in each eye. A full blink was recorded if the blink probability was ≥ 90% in both eyes and ≥ 95% in at least one eye, ensuring high detection specificity.

Finally, participants engaged in a previously validated “blink test” as a proxy measure for tear film stability. [38–40] Instructions were provided to participants to blink and then refrain from blinking until perceiving ocular discomfort or blinking again. Participants indicated the start time (their final blink) by touching the iPad screen, and touching it again once discomfort occurred or if blinking was necessary. A mean of three test measures was expressed as “stare time”. Participants were explicitly advised that this was not a conventional “staring contest”, that the eyes were not to be opened unnaturally wide, and that the goal was not to win, but to establish the time until the onset of ocular discomfort.

Participants were encouraged to hold the iPad in their preferred position to replicate habitual digital device use to promote natural blinking patterns, and blinking was measured covertly. Participants were informed only that the front-facing camera was “tracking their eyes” and were prompted by the software if their eyes were outside the camera field of view. Full disclosure and explanation were provided after the survey and clinical advice on healthy screen use habits and dry eye disease was provided.

Statistical analysis

Data were imported from raw files, then analysed in RStudio (version 1.4.1106, Boston, USA) [41] using the R statistical language (version 4.1.0, Vienna, Austria). [42] Normality testing was performed using the Kolmogorov-Smirnov test, showing most variables to be non-normally distributed. For non-parametric data, comparisons between factors used the Wilcoxon rank-sum test, while correlations used Kendall’s Tau. [43] Parametric comparisons used either independent t-tests with Holm multiplicity correction [44] or one-way ANOVA, dependent on the number of factors, while correlations used Pearson’s product-moment correlation coefficient. Linear models were also created to calculate 95% confidence intervals. P-values < 0.05 were considered significant.

RESULTS

A total of 456 participants, aged 24±10 years, 38% female, completed the survey and were included in the analysis. Demographic characteristics, survey responses and test results are summarised in Table 1.

Table 1: Study participant demographics and study results. Means ± SD, counts (percentage) and medians (IQR) are reported, as appropriate.

Demographics	
Sample size	456
Age, range (years)	24±10, 13-75
Female gender	175 (38%)
European ethnicity	230 (50%)
East Asian ethnicity	59 (13%)
South Asian ethnicity	19 (4%)
Maori or Pacific Island ethnicity	79 (17%)
Other ethnicities	69 (15%)
Habitual contact lens wearer	39 (9%)
Time taken to complete survey (minutes)	2.1±0.7
Self-reported screen use habits	
Daily weekday screen time (hours)	6.7±3.6
Daily weekday gaming time (hours)	2.4±3.0
Daily weekend screen time (hours)	5.8±4.1
Daily weekend gaming time (hours)	3.1±3.6
Total weekly screen time (hours)	43.7±24.4
Total weekly gaming time (hours)	17.5±21.4
Dry eye symptomology	
SANDE score (out of 100)	33±18
DEQ-5 score (out of 22)	11 (8-13)
Quality of life	
Impact severity of dry eye on daily life tasks (out of 100)	25±21
Impact severity of dry eye on vision related quality of life (out of 100)	28±22
Blinking parameters	
Blink rate (blinks/minute)	12.6±11.1
Tear film stability proxy	
Blink test (s)	19.6±14.2

Overall, participants reported a median of over 40 hours of screen time in total per week; however, this was non-normally distributed (Kolmogorov-Smirnov, D = 0.08, p = 0.004) with a long right-tail and skewness of 1.09 (Figure 1A). Males and females reported similar weekly screen time (median hours (IQR): males 40.0 (25.1-55), females 41.5 (27-57), p=0.599), but of this screen time, males reported more hours spent gaming than females (median hours (IQR) males 14.0 (6-30), females 6.5 (2-16), p<0.001, Figure 1B). Total screen time and gaming hours were well correlated (r=0.613, p<0.001). Total screen time increased with age (r=0.125, p=0.007), while gaming hours decreased with age (r=-0.264, p<0.001).

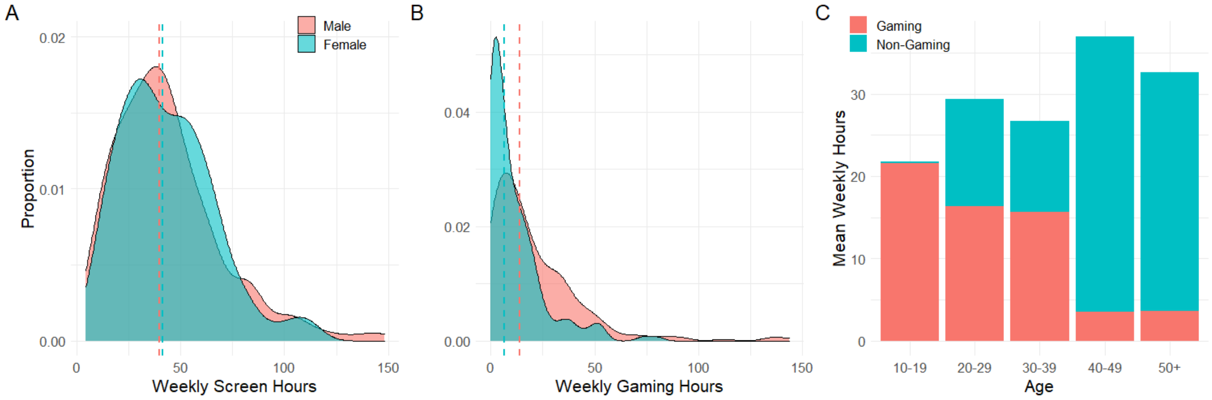

Figure 1: Distribution of self-reported total weekly screen and gaming time by gender. Dotted lines indicate median values. There was no significant difference in weekly screen hours by gender (p = 0.599), however, males spent more than twice as much time gaming as females (p < 0.001). There was a positive relationship between weekly screen hours and age (p = 0.007), and a negative relationship between the proportion of that screen time spent on gaming with age (p < 0.001)

Ninety per cent of all respondents qualified as symptomatic for dry eye disease according to the TFOS DEWS II consensus symptomatic diagnostic criterion of DEQ-5 ≥ 6. [36,37,45] Blink test results of < 10 seconds, indicating reduced tear film stability, were observed in 24% of the sample; of note, all these participants also had DEQ-5 ≥ 6. Overall, discomfort levels were higher in females versus males (p<0.001) and were associated with extended screen time only in females. Symptoms were also associated with faster blink rates and shorter blink test times (Table 2; Figure 2). Overall, participants reporting extended screen use exhibited more rapid blink rates and poorer symptomology (Table 2; Figure 3). These associations are depicted in Figure 4. There was a significant correlation between blinks per minute and DEQ-5 score (p = 0.019), with no difference by gender (p = 0.543). Similarly, with the blink test, there was a significant negative correlation between stare time and DEQ-5 score (p=0.012), and again no difference between genders (p = 0.475). Overall, shorter blink test times were associated with elevated blink rates (r=-0.11, p=0.02).

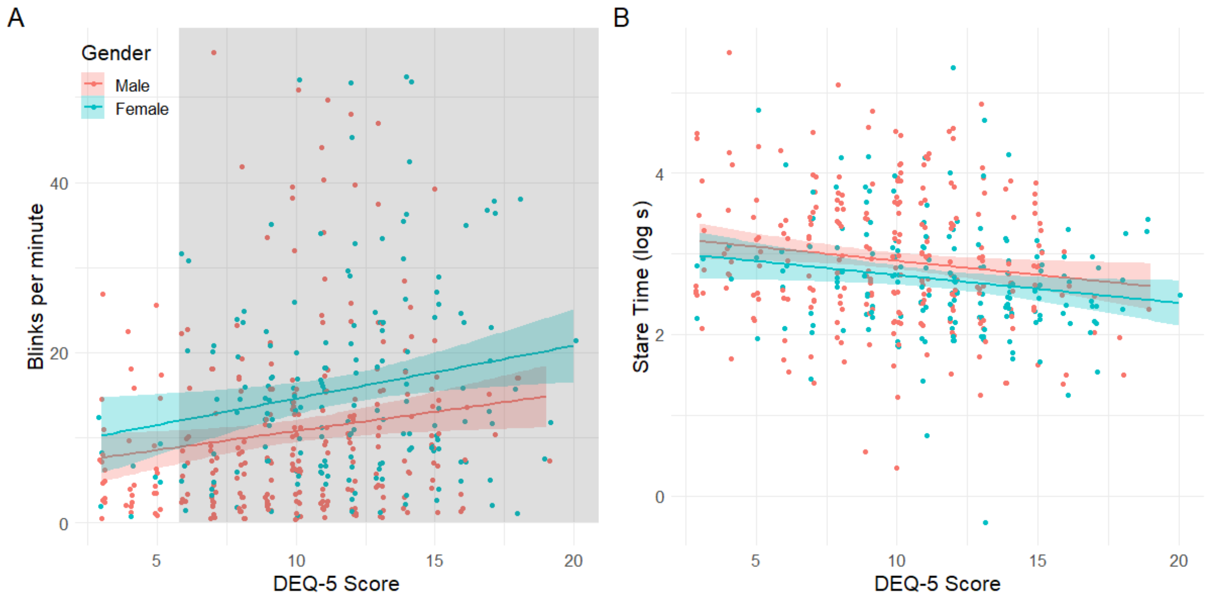

Figure 2: Raw distribution and linear regression analysis of (A) blink rate, and (B) blink test against DEQ-5 score, between males and females. The shaded grey area indicates a DEQ-5 score (≥ 6) considered positive for dry eye symptomology. [36,37,45] There was a significant correlation between blinks per minute and DEQ-5 score ($p = 0.019$), with difference by gender ($p = 0.543$). Similarly, there was a significant negative correlation between the blink test and DEQ-5 score ($p=0.012$) and no difference between genders ($p = 0.475$). Shaded areas over the regression lines represent 95% confidence intervals, while dots are individual data points with jitter added along the x-axis to prevent overlapping points.

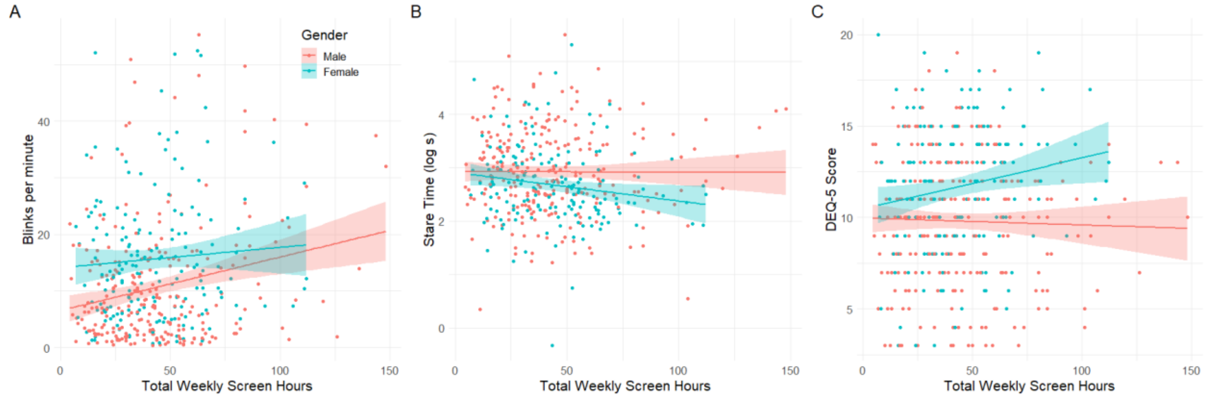

Figure 3: Distribution of (A) blink rate, (B) blink test, and (C) DEQ-5 score according to total weekly screen time between genders. Regression lines and surrounding shaded areas indicate 95% confidence interval, by gender. There was a significant relationship between (A) total weekly screen hours and blinks per minute ($p < 0.001$), and females had a higher blink rate than males ($p < 0.001$). There was no relationship between (B) the blink test and total weekly screen hours ($p = 0.957$), and no difference in stare time between genders ($p = 0.938$). There was no significant relationship between (C) screen time and DEQ-5 score overall ($p = 0.642$), however there was a significant interaction between extended screen time and higher DEQ-5 scores in females ($p = 0.028$).

Table 2: Linear regression model for screen time, gaming time, age, and DEQ-5 score, with interaction by gender (p-values)

	SCREEN TIME	**Gender**	**Interaction**
Blink Rate	*<0.001	*<0.001	0.193
Stare Time	0.957	0.938	0.110
DEQ-5	0.642	0.470	*0.028
	GAME TIME	**Gender**	**Interaction**
Blink Rate	*0.001	*<0.001	0.523
Stare Time	0.128	0.089	0.383
DEQ-5	0.791	*<0.001	0.751
	AGE	**Gender**	**Interaction**
Blink Rate	0.855	0.106	0.855
Stare Time	0.390	0.124	0.693
DEQ-5	0.656	*0.028	0.931
	DEQ-5	**Gender**	**Interaction**
Blink Rate	*0.019	0.543	0.574
Stare Time	*0.012	0.475	0.985

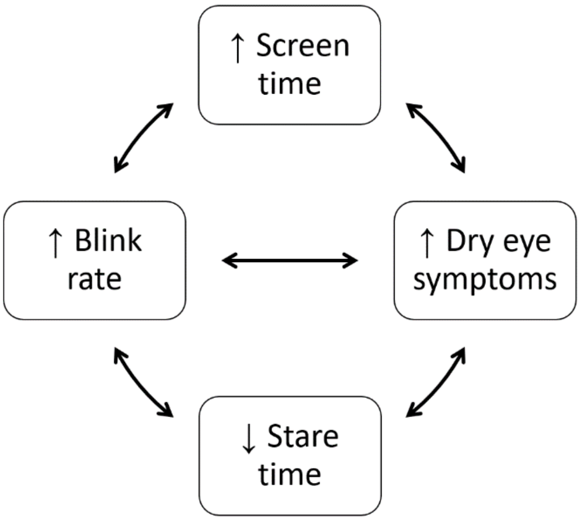

Figure 4: Schematic association between study variables. Double-ended arrows indicate correlations (p<0.05)

DISCUSSION

A sizable proportion of the young population explored in this study reported clinically significant discomfort symptoms which were found to be associated with extended screen time, elevated blink rates, and reduced stare times (Figure 4). More frequent reflex blinking is a compensatory mechanism common in DED patients, triggered by reduced tear film stability and the resulting discomfort. [30] Ninety per cent of the sample manifested clinically significant levels of discomfort based on the accepted cut-off for DEQ-5 ≥ 6. At the same time, nearly one in four participants exhibited evidence of both positive symptoms and a clinical sign, as required for the diagnosis of DED, according to the TFOS DEWS II criteria. [36,46]

Young people are not immune to signs and symptoms of dry eye disease. [25,28] Although the current study design cannot confirm causality, these findings suggest that extended screen time seems to place young populations at risk of deteriorating ocular health, comfort, and quality of life. [24,25] The average weekly screen time of over 40 hours (the equivalent of a workweek in screen time) might be considered relatively high for a young cohort, but is likely similar to current levels of screen use experienced widely in response to the COVID-19 pandemic. These effects observed in gamers, who may be reflective of long-term extended screen time users, may forecast an exacerbation of symptoms associated with increased screen time in the general population in the future.

Females have higher blink rates and higher rates of dry eye symptoms, which was also observed in the current study using both objective and subjective measures. This largely pre-menopausal cohort and other age-matched studies suggest that even young females may be at an elevated risk of developing DED. [47] A relationship between DED symptoms and increasing screen hours was significant only in females, which is likely to be due to the higher level of severity in this group and the resulting greater symptomatic range. Extended screen time was, however, associated with elevated blink rates for both genders. The association between extended screen time and proxy tear film stability was comparable between genders, but subsequent, more highly powered studies may be beneficial to elucidate subtle differences. The possibility that young attendees of a gaming convention might tend to give in to competitive nature and attempt to “win the staring contest” (despite instructions to the contrary) and understate their symptoms cannot be excluded.

Gaming time, reported in greater proportions by males, did not appear to be an independent risk factor for DED. In a previous study on normal subjects, NIBUT decreased significantly after 30 min of playing an unspecified computer game. [48] Besides the time spent using a digital screen, other factors such as device type, position and content can affect blinking dynamics. Cognitively demanding tasks, such as action-based games (e.g. first-person shooters or racing games), greatly impact blinking dynamics. [49] Gaming amounted to a relatively small proportion of the total daily screen time reported in this study. This might imply that the impacts on ocular surface physiology and associated discomfort and quality of life might be driven or compounded by other daily tasks relating to school, work, communication, and leisure digital activities, rather than gaming. Self-reported quality of life scores are in line with those obtained in a study on a population of similar age (average age 21±3 years, range: 17–31), wherein a quality of life score of 27±16 (out of 100) was associated with moderate dry eye. [50]

Modern digital media consumption is pervasive and multifaceted and therefore challenging to measure accurately, with usage duration and frequency being regularly underestimated and underreported. [51,52] Self-reported measures of screen use may therefore be inadequate to assess its impacts. More objective, granular measures of device type, usage, content, and interactions obtained by integrated tracking software may be preferable, but its implementation is often hampered by privacy concerns. The automated, objective and especially covert blink detection method used herein adequately detected overall higher blink rates in females and correlated with dry eye symptoms, lending support to the validity of this method. The evaluation of blink rates during screen use is representative of our current, predominantly screen-based lifestyles. The methods in this study precluded assessment of incomplete blinking, a potentially more informative predictor and driver of DED associated with screen use, [27,29,53] or the wide variation in blink rates known to occur with high cognitive loads during screen use, such as with gaming. However, such efforts, incorporating abbreviated, clinically validated diagnostic test batteries, may be advantageous for large-scale evaluations or screenings in non-clinical settings, and could potentially also promote greater reliability and repeatability in blinking research. [31,36,54,55]

These findings underpin the emergence of an increasingly common paediatric form of dry eye disease and its association with extended screen time, using the habits of gamers as a representative proxy for the effects of extended and long-term screen-based work, school, and leisure. Integrating screening and educational initiatives into and beyond routine clinical practice for young patients, alongside advocating for lifestyle and behavioural changes such as blinking exercises and rules around reducing screen time, may become established as essential preventative measures against the onset and progression of dry eye disease. The emerging evidence-base on the wide-ranging impacts of extended screen time in youth should be consolidated and prioritised to support the development and implementation of guidelines on safe screen use in and outside of educational settings.

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