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Association Of Digital Device Usage And Dry Eye Disease In School Children

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Abstract
Purpose: *To investigate the influence of digital device use (computers, laptops, tablets, smartphones) on dry eye disease (DED) in a pediatric population.*
Settings and Design: *This was a cross-sectional study. School children studying in grades 5–9 at two private schools.*
Methods: *In this study, 462 children underwent ocular examination including tear film breakup time (TBUT) and Schirmer's test. Questionnaires were administered for collecting information on the type and duration of digital device usage separately for academic and leisure activities and the Ocular Surface Disease Index (OSDI) score.*
Results: *The mean age of participants was 11.2 + 1.4 years, and 63% were boys. The mean OSDI score was 37.2 + 11.8, and 90.5% had symptoms of DED. Children with moderate to severe DED (n = 88, 19%) had longer daily duration of device use and lower Schirmer's test and TBUT values compared to children with mild DED (P = 0.001). A cumulative exposure time of more than 3–3.5 h per day had a significantly increased risk of DED. Multivariable logistic regression analysis showed that increment in computer usage (odds ratio [OR] 1.94 for every half an hour increase, 95% confidence interval [CI] = 1.2–3.1) and children studying in higher grades (OR 1.30, 95% CI = 1.1–1.6) had a higher risk of moderate to severe dry eye.*
Conclusion: *Cumulative device exposure time of more than 3–3.5 h per day had a significantly increased risk of pediatric DED. Children with an increment in computer usage by half an hour per day had a higher chance of experiencing moderate to severe dry eye. Policymakers should aim to restrict the screen time below 3 h on a daily basis.*

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I. Introduction-

Advances in digital technology in the form of laptops, electronic tablets, smartphones, and the applications that populate them have radically transformed our lives over the last two decades. The inevitable rise in youth digital media consumption brings a new challenge of ocular problems and digital eyestrain at an early age. Children's mobile device (e.g., smartphone, tablet) access and ownership has grown substantially in the past decade.[1-8] In addition to education and schoolwork, children use mobile devices to play games, watch videos, communicate, take pictures, and access applications (apps). According to Common Sense Media's nationwide survey, 95% of children aged 0–8 years used a mobile device in 2017, with 42% of young children having their own tablet device.[4] Kids aged 8 and under spend an average of 2 h and 19 min a day with screen media.[4] A study including children aged 9–11 years from 12 countries showed that 54.2% of the children exceeded proposed screen time guidelines (≤2 h per day).[6] Concerns exist regarding excessive use and the impact of frequent usage of digital media on children's health and well-being.

Increased and continuous exposure to visual display devices such as computer screens, laptops, tablets, and smartphones for various activities have led to higher incidence of dry eye in adults, with an estimated prevalence of near 50% for those using devices for long hours.[9,10] However, dry eye disease (DED) is often underestimated or overlooked in children, or attributed to other causes like ocular allergies or secondary to inflammatory and autoimmune etiologies such as juvenile rheumatoid arthritis and Sjögren syndrome. Several studies report an incidence of 6%–10% of dry eye among school going children and link this to increase in smartphone use time.[11-16] Recently, Rojas-Carabali et al. reported a 33% incidence of dry eye in 60 apparently healthy children between 7 and 17 years of age and attributed this to increased screen time.[17] Kim et al. reported that longer daily smartphone use was associated with a higher likelihood of having multiple ocular symptoms (five to seven symptoms out of seven symptoms; P = 0.005) in adolescents.[18]

Though the temporal relationship between DED and screen time is well established in adults, this is not well proven in children. Questions remain about the maximum permissible screen time for children before dry eye symptoms set in and whether there is a dose-dependent relationship between severity of symptoms and duration of screen time per day. In addition, there is no clear understanding on whether any one type of screen leads to more dry eye symptoms than others.

In this cross-sectional study conducted before the coronavirus disease 2019 (COVID-19) pandemic, we aimed to understand the prevalence of DED in urban schools in western India, study the impact of different devices on the ocular surface, and identify a maximum permissible time, beyond which the screen time leads to significantly higher risk of DED in children.

II. Methods

This was a cross-sectional study approved by the institutional ethics committee and was performed in accordance with the tenets of the declaration of Helsinki. Informed consent was obtained from the school principals as well as from individual parents of all participating children. School children studying in grades 5–9 at two private schools. Children whose parents provided consent for participation were recruited.

All children underwent ophthalmic evaluation in the school premises, including uncorrected visual acuity, dynamic refraction, and slit-lamp evaluation of the anterior segment, to determine the tear film breakup time (TBUT) using standard procedures. Children also underwent the Schirmer's test as per protocol. It was performed with the help of a 5 × 35 mm strip of the Whatman-41 filter paper. The strip was folded 5 mm from one end and kept in the lower fornix of both eyes at the junction of lateral one third and medial two thirds. After 5 min, the strips were removed and the length of filter paper wetted was noted in millimeters. The values of Schirmer's test and TBUT from the worse eye, that is, eye with lower values, were used for analysis. In case the values were similar, the value from the right eye was considered.

The Ocular Surface Disease Index (OSDI) questionnaire was administered to participating children in the school by an interviewer masked to the clinical status of the child. All responses to the OSDI questionnaire were converted to an OSDI score ranging between 1 and 100 based on the formula OSDI = [(sum of scores for all questions answered) ×100]/[(total number of questions answered) ×4]. To evaluate the use of devices at home, we gave a previously validated questionnaire to the children and asked parents to fill out and return it within 1 week. The OSDI questionnaire used was developed by the Outcomes Research Group at Allergan Inc (Irvine, CA, USA), and is a 12-item questionnaire designed to provide a rapid assessment of the symptoms of ocular irritation consistent with DED and their impact on vision-related functioning. The questionnaire asked for the amount of time spent (in hours) per day separately on computers (including laptops and tablets) and smartphones for 1) education, 2) extracurricular activities (such as reading e-books, other reading material, viz. for making projects, etc.), and 3) other activities such as gaming, watching cartoons and related videos, etc., Additional questions included in the questionnaire were the duration of watching television and duration of reading physical books. Parents were asked to estimate these times over the preceding 4 days to avoid recall bias.

Outcome measures

The outcome measures were differences in exposure time to various devices between various grades of DED, as assessed by the OSDI questionnaire.

Statistical analysis

The OSDI scores were used to classify participants into normal (OSDI <23), mild dry eye (OSDI >23 and <45), and moderate to severe dry eye (OSDI >45). In view of smaller numbers, the categories of moderate and severe dry eye were combined and labeled as "moderate to severe dry eye" for statistical analysis.

All continuous variables were expressed as means with standard deviation or median with interquartile range (IQR), while categorical variables were expressed as proportions (n, %). Group differences between continuous variables were analyzed using analysis of variance (ANOVA) or the Kruskal–Wallis test in case of nonparametric distribution, while differences between categorical variables were assessed using the Chi-square or Fischer's exact test. Factors predicting the OSDI score were analyzed using univariate and multivariable linear regression analyses. Variance inflation and other regression diagnostics were used to identify covariates in the best fit model. Similarly, risk factors for moderate to severe dry eye based on the OSDI score were analyzed using univariate and multivariable logistic regression analyses. Receiver operating characteristic (ROC) curves were set up to separately identify the predictive accuracy of the various covariates to detect moderate to severe dry eye compared to normal eyes and were presented as area under ROC (AUROC) along with its standard error and 95% confidence interval (CI). The Youden index was used to identify the best cut-off value of total time of device use from the predicted AUROC, and the sensitivity and specificity for identifying moderate to severe dry eye at the best cut-off points were reported.

All data were stored in Microsoft Excel and analyzed using STATA 12.1 I/c (Stata Corp, Fort Worth, TX, USA). All P-values <0.05 were considered statistically significant.

III. Results

We included data from 462 children who satisfied the inclusion criteria and had complete data from the OSDI questionnaire. The mean age of participating children was 11.2 + 1.4 years (range: 9–14 years), and 290 (63%) of them were boys. The mean overall OSDI score of the participating cohort was 37.2 + 11.8 (range: 6.8–86.4). Based on the OSDI grading, 44 (9.5%) participants were normal, 332 (72%) had mild dry eye symptoms, and 88 (19%) had moderate to severe symptoms of dry eye. Table 1 shows a comparison between different levels of dry eye based on the OSDI score. Children who experienced moderate to severe dry eye symptoms used the computer/ laptop/mobile phone for significantly longer durations over each day as well as had higher total hours used either for education purposes or for extracurricular activities and other purposes over the previous 4 days. Those without dry eye symptoms used each device typically for under 1 h per day, while those with mild dry eye symptoms used devices for 1½ h per day and those with moderate to severe dry eye used each device for nearly 2 h a day. Similarly, children with moderate to severe dry eye had lower readings on the Schirmer's test

Table 1: Comparison between different levels of dry eye based on the OSDI score

Variable	Normal (*n*=44)	Mild dry eye (*n*=332)	Moderate–severe dry eye (*n*=88)	*P*
Age (years)	10.2±1.2	11.1±1.3	11.6±1.6	0.003
Gender (% boys)	34 (77%)	210 (63%)	46 (52%)	0.02
Using spectacles	15 (34%)	139 (42%)	33 (37%)	0.48
Treated for dry eye in the past	8 (18%)	94 (28%)	26 (29%)	0.32
OSDI score	16.4±4.1	35.4±6.1	54.5±7.9	<0.001
Reading time▪	1.7±0.8	1.6±1.2	1.9±1.2	0.10
Computer for education▪	0.5±0.6	1.5±0.9	1.8±1.0*	**0.001**
Computer for extracurricular activities▪	0.8±1.0	1.5±1.1	1.8±1.3**	**0.001**
Mobile for education▪	0.8±1.2	1.6±1.1	1.8±1.2	**0.001**
Mobile for extracurricular activities▪	1.2±0.9	1.5±0.9	1.6±1.1	0.07
Mobile for other purposes▪	2.1±1.7	3.1±1.6	3.4±1.7**	**0.001**
Watching television▪	1.5±0.9	1.7±0.9	1.9±1.1	0.24
Total hours of screen time over 4 days	7.1±4.2	11.1±4.3	12.4±4.8*	**0.001**
Schirmer's test 1				**<0.001***
Normal (>15 mm)	32 (73%)	136 (41%)	28 (32%)	
Mild dry eye (9-14 mm)	12 (27%)	171 (52%)	39 (44%)	
Moderate dry eye (4-8 mm)	0	22 (7%)	16 (18%)	
Severe dry eye (<4 mm)	0	1 (<1%)	5 (6%)	
Tear film breakup time				**<0.001***
Normal (>10 mm)	22 (50%)	89 (27%)	13 (15%)	
Mild dry eye (5-10 mm)	14 (32%)	92 (28%)	28 (32%)	
Moderate dry eye (2-5 mm)	8 (18%)	111 (34%)	20 (23%)	
Severe dry eye (<2 mm)	0	38 (11%)	27 (30%)	

And TBUT compared to normal children. All children within each group used computers/laptops and mobile phones for an equal amount of time.

Groupwise comparisons between children with mild dry eye and those with moderate to severe dry eye showed that the mild dry eye group used computers for education for significantly shorter durations [Table 1]. However, total time for device use over the preceding 4 days and use of computers for extracurricular activities and mobile phones for other purposes were only marginally lower in the mild group. There were no differences in other parameters such as use of mobile phones for education and extracurricular activities. Differences between Schirmer's test and TBUT were statistically significant between mild and moderate to severe dry eye groups. On dividing the participants into tertiles based on the OSDI score, we found similar trends [Supplemental Table 1] with children having higher OSDI score using devices for significantly longer durations for education, extracurricular and other activities compared to those with lower OSDI scores.

On univariate linear regression analysis [Table 2], we found that increasing age, female gender, being in higher grade in school, and using all devices for longer hours were associated with higher OSDI scores [Table 2]. On multivariable analysis, using best fit modeling techniques, we found that increasing use of computers for education led to the highest increment in OSDI score (OSDI score increased by 5.8), with 95% children experiencing between 3.8 and 8.1 OSDI score increment with every half an hour increment in computer use. Increasing time on mobile use for extracurricular and other activities such as gaming also led to significantly more dry eye symptoms [Table 2]. Interestingly, greater book reading time led to lower OSDI score, that is, lesser dry eye symptoms, though this was not statistically significant (P = 0.44).

On assessing the factors predictive of moderate to severe dry eye using logistic regression analysis [Table 3], we found that increment in computer use by every half an hour per day led to 94% increment in likelihood of moderate to severe dry eye (P = 0.005). In addition, children studying in higher grades had a 30% higher chance of experiencing moderate to severe dry eye compared to children studying one grade lower. Other factors such as duration of mobile use for education or other activities did not predict this significantly. When considering the influence of cumulative 4-day time of device use, we found that every 1-h increment led to 9% increment (95% CI = 1.03–1.15, P = 0.001) in the likelihood of moderate to severe dry eye compared to those with normal or mild dry eye, with an AUROC of 0.59 (95% CI = 0.55–0.64). In addition, a cumulative device exposure of more than 3 h per day led to significantly higher risk of moderate to severe dry eye, with a prediction sensitivity of 68% and specificity of 62%. Similar analysis with Schirmer's test showed a 45% increased likelihood (odds ratio [OR] =1.45, 95% CI = 1.31–1.61, P < 0.001) of experiencing moderate to severe dry eye with 3.5 h of cumulative device exposure per day, with an AUROC of 0.87 (95% CI = 0.83–0.90) and a prediction sensitivity of 77% and a specificity of 79%.

Table 2: Univariate and multivariable linear regression analyses for factors influencing the OSDI score

		β coeff	95% CI	β coeff	95% CI
Age	1-year increment	1.62*	0.8-2.3	—	—
Gender	Girls versus boys	2.34*	0.1-4.5	—	—
Grade of school	One grade higher	2.07*	1.2-2.8	—	—
Reading time	Half an hour increment daily	0.58	-0.3 to 1.5	-0.33	-1.2 to 0.52
Computer use for education	Half an hour increment daily	**7.28****	**5.3–9.2**	**5.84****	**3.6–8.1**
Computer use for extracurricular activities•	Half an hour increment daily	5.49**	3.6-7.4	—	—
Mobile use for education•	Half an hour increment daily	5.38**	3.5-7.2	—	—
Mobile use for extracurricular activities	Half an hour increment daily	4.02**	1.9-6.1	1.83*	0.83-5.1
Mobile use for other activities	Half an hour increment daily	3.75*	2.5-4.9	2.61*	0.6-4.3
TV watching	Half an hour increment daily	0.12	-0.7 to 1.5	—	—
Total time over 4 days•	Half an hour increment	1.85	1.4-2.3	—	—

Table 3: Univariate and multivariable logistic regression analyses for factors predicting moderate to severe dry eye

		OR	95% CI	OR	95% CI
Age•	1-year increment	1.29*	1.1-1.5	—	—
Gender	Girls versus boys	1.71	1.1-2.7	1.5	0.9-2.4
Grade of school	One grade higher	1.37*	1.1-1.7	**1.30***	**1.1–1.6**
Reading time	Half an hour increment daily	0.91	0.5-1.4	—	—
Computer use for education	Half an hour increment daily	**2.25****	**1.4–3.5**	**1.94****	**1.2–3.1**
Computer use for extracurricular activities	Half an hour increment daily	1.82**	1.2-2.8	1.28	0.6-2.7
Mobile use for education•	Half an hour increment daily	1.51*	1.0-2.3	—	—
Mobile use for extracurricular activities	Half an hour increment daily	1.35	0.8-2.1	—	—
Mobile use for other activities	Half an hour increment daily	1.33*	1.0-1.7	1.0	0.9-1.3
TV watching	Half an hour increment daily	1.63	0.9-2.5	—	—
Total time over 4 days•	Half an hour increment	1.19**	1.1-1.3	—	—

IV. Discussion

In this study, we found that nearly 90% of children with age ranging from 9 to 14 years had some form of dry eye symptoms based on the ODSI score, when using devices for education or other purposes. The effect of devices on ocular surface was dose dependent, that is, greater cumulative exposure time of more than 3–3.5 h per day led to a significantly increased risk of ocular surface disruption, measured both subjectively and objectively. Children with an increment in computer usage by half an hour per day and children studying in higher grades had a higher chance of experiencing moderate to severe dry eye. In addition, reading time using physical books was associated with lower OSDI scores and better ocular surface health.

The connection between the usage of smartphones and video display terminals (VDTs) and the development of dry eyes was first established in the landmark study by Moon et al.[3] In a study on 288 Korean children, they reported that duration of smartphone use and total daily duration of VDT use were associated with increased risk of DED.[11] Subsequently, in another study on 916 children, aged 7–12 years, from urban and rural settings, Moon et al.[3] further reported that the mean daily duration of smartphone use was significantly higher (3.18 ± 0.97 h) in the DED group compared to the normal group (0.62 ± 0.68 h), and prolonged smartphone use was a strong risk factor for pediatric DED (OR = 13.07, P < 0.001). These results are similar to our study, where we found that a cumulative device exposure of more than 3.5 h per day led to 45% increased likelihood of experiencing moderate to severe dry eye, assessed with Schirmer's test. We found that increasing use of computers for education led to the highest increment in OSDI score, with 95% children experiencing between 3.8 and 8.1 OSDI score increment with every half an hour increment in computer use. Increasing time on mobile use for nonacademic activities such as gaming also led to significantly more dry eye symptoms. The findings from our study should help parents, teachers, as well as policymakers to restrict screen time below 3 h on a daily basis.

Similar results were obtained in a study by Rojas-Carabali et al. who described the ocular surface characteristics and ocular surface tests' results in a healthy pediatric population of age 7–17 years.[18] They noted that 100% of their participants used screen devices daily, with a mean daily screen time of 5.59 ± 2.77 h. They found that all the participants had at least one abnormal ocular surface test result and 33.33% had Diagnosis of DED,according to the Dry Eye Workshop (DEWS) II Diagnostic Methodology report published by Tear Film and Ocular Surface Society (TFOS). Diagnostic Methodology report (TFOS DEWS II) and they linked it to device usage.[14] Choi et al. reported that subjects who spent more than 4 h using a smartphone experienced more subjective computer vision syndrome (CVS) scores (fatigue, burning, and dryness) and higher total OSDI scores compared to the computer display group.[9-14] In addition, decreased blink rate and frequent incomplete eye closure were also noted in the smartphone group. Smartphones are used with short watching distances due to their small light-emitting diode (LED) screens, thus inducing ocular fatigue, glare, and irritation.[9] Uchino et al. observed that VDT workers had short TBUT and increased corneal fluorescent staining, despite normal lacrimal function.[20] Decreased blink rate and increased interpalpebral ocular surface area during the use of VDTs may increase tear evaporation due to destabilization of the tear film, thus inducing DED.[9] Moon et al. also reported that cessation of smartphone use for a 4-week period in children with DED resulted in significant improvements in noninvasive TBUT, punctate epithelial erosion, and OSDI scores, with all affected children no longer being classified as DED sufferers at the end of the abstinence period.[3] In a study on 78 children aged 5–15 years, Dash et al. reported that 10.6% of children had DED with an average of 5.33 h spent on smartphones and VDT. Improvement in ODSI scores and mean TBUT was noted after cessation of smartphone use for 1 month.[15]

We also found in our study that children studying in higher grades had a 30% higher chance of experiencing moderate to severe dry eye compared to those studying one grade lower. Moon et al. also reported similar results, wherein the risk for DED was higher in older children (9.1% in grades 4–6) than in lower grades (4% in grades 1–3).[3] They noted that the rate of smartphone use was higher and the mean daily duration of VDT was longer in older grades, which may have led to the higher DED prevalence in older graders.[1] In our study, DED prevalence was also found to be higher in females than males. There was no difference between the two groups with regard to VDT use. In general, DED is more commonly found among females in adults with DED.[18]

An interesting aspect in our study was that reading time using physical books led to lower OSDI score, that is, lesser dry eye symptoms and better ocular surface health, though this was not statistically significant. Desktop and laptop computer screens are frequently viewed in horizontal gaze, and so, the palpebral aperture is wider than for conventional book reading, which is usually performed in downgaze. As a result, a larger ocular surface area is exposed to the effects of tear film evaporation. In addition, VDTs and liquid crystal display (LCD) tablet screens are backlit and emit glare and may have micro screen flickers, which makes the eyes work harder to focus. Reduced blink rate and incomplete blinking are more common when focusing on a backlit screen, and this causes tear film instability, dry eyes, and visual fatigue.[20] Incomplete blinking, where the upper eyelid does not cover entire corneal surface, can result in increased evaporation and tear film break up due to inadequate spread of the tear film and reduced tear film thickness in the inferior corneal region. This may be more pertinent to dry eye than the absolute blink rate.

As tear film stability can be maintained with a reduced blink rate, provided that most blinks are complete.[21] Argilés et al.[22] observed that reading from a hard copy was associated with a significantly lower proportion of incomplete blinks (0%–5%) compared to reading from a tablet (14.5%), expanded computer display (13.5%), or electronic reading (9%). Benedetto et al. compared prolonged reading on three different media (LCD display, E-ink display, and paper book) to estimate their effects on visual fatigue.[1] They noted that prolonged reading on LCD led to a larger decrease in the number of blinks, pupillary size, and increased perceived visual fatigue, compared to reading on E-ink or paper book. The specific influence of digital devices on incomplete blinks is unclear, and further research is needed to address this issue, along with the possible benefits of blink training and probable benefits of book reading.

Our study had some limitations. Our study was aimed at school children, so there may have been differences in self-reporting and expression of ocular discomfort and comprehension of the questionnaire between younger graders and older graders, which could have affected our estimates of DED prevalence. Secondly, enrollment in this study was limited to students of urban private schools, and therefore, results may not be representative of other populations (students of government schools or rural schools). There may be other confounding factors such as socioeconomic status, family composition, dual income family status, or environmental factors. We used subjective symptom criteria (OSDI score) and objective signs (low TBUT and Schirmer's test) to diagnose DED. These criteria were based on adults, and the true prevalence of DED in school children may be different due to the use of adult-targeted diagnostic criteria. Also, DED usually coexists with allergic conjunctivitis,[22] and it is difficult to separate children with DED from those with ocular allergies in view of similar symptoms, which may have affected the prevalence of DED.

V. Conclusion

We found that nearly 90% of children with age ranging from 9 to 14 years had some form of dry eye symptoms when using devices for education or other purposes. Greater cumulative exposure time of more than 3–3.5 h per day leads to a significantly increased risk of ocular surface disruption. Children with an increment in computer usage by half an hour per day had a higher chance of experiencing moderate to severe dry eyes. Parents, teachers, as well as policymakers should aim to restrict the screen time below 3 h on a daily basis and advocate following the 20/20/20 rule: look away from the screen every 20 min, focus on an object at least 20 feet away, for at least 20 s. Children should be encouraged to take frequent breaks by taking a walk away from the screen for at least 10 min every hour. Using a simple timer or software program to turn off the screen at regular intervals can help the child remember.

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