RESEARCH

After-effect on Tear Film Quality and Quantity of Reading on Laptop Computer Screen versus Hard-Copy

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Running Title: Effect of Screen vs. Hard-Copy Reading on Tear Film

Key words: computer screen; hard-copy; laptop; non-invasive tear break-up time; reading; strip meniscometry; tear film.

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ABSTRACT

Clinical Relevance

Electronic displays, including laptops, tablets, and smartphones, have dramatically altered the way information is accessed and become significant factors in human daily life. They interfere with the blink rate and increase dry eye symptoms, which leads to more discomfort compared to hard-copy while reading.

Background

Digital eye strain occurs when an individual suffers from symptoms, or they are exacerbated, while performing a task requiring digital screen viewing. This study assessed the tear film status immediately following reading on a laptop computer screen versus an identical hard-copy.

Methods

30 young adults with normal ocular health and reporting no significant symptoms of dry eye (ocular surface disease index (OSDI) score < 13 and non-invasive tear breakup time (NITBUT) > 10 seconds) read a text as hard-copy and on a laptop computer screen for 30 minutes on separate days in a randomized sequence in a controlled reading experimental condition. The texts were matched in size and contrast, and presented at a viewing distance of 40 cm. The NITBUT and strip meniscometry tube tests were administrated at baseline and after reading in both conditions.

Results

The median baseline NITBUT decreased from 13.0s to 10.0s (P<0.001) after hardcopy reading and to 7.0 (P<0.001) after reading from a laptop computer screen, with a significant difference between the task medium (P=0.001). The baseline strip meniscometry tube results decreased from 6.7mm to 5.0mm (P<0.001) after hardcopy reading and to 5.0mm (P<0.001) after reading from a laptop computer screen, but there was no significant difference with the task medium (P=0.085).

Conclusion

Reading in both conditions led to tear film instability in terms of the tear film quality and quantity. Additionally, the computer screen has a greater impact on the TBUT compared to hard-copy reading, while these two reading mediums had the same effect on the tear volume.

INTRODUCTION

Reading text presented in hard-copy or on computer screens is considered one of the most common cognitive near-vision tasks.[1] Modern lifestyle requires increasingly demanding visual tasks such as reading books for leisure or using electronic devices for non-vocational activities.[2] Increased demand for long-term reading in modern life has been reported to play an important role in the development of dry eye disease.[3] The high cognitive demands associated with a reading task can lead to dry eye symptoms, due to decreased and partial blinking.[1] Ocular discomfort symptoms after sustained reading are not specific to patients with dry eye, as even healthy individuals with no history of dry eye experience such visual symptoms after prolonged reading;[4] however, problems with reading are the most common and probably the most significant functional complaint of individuals with dry eye and may lead to a decrease in quality of life.[5, 6]

It has been reported that 64-90 % of computer users experience visual symptoms, which may include eyestrain, ocular discomfort, dry eye, and blurred vision either at near or when looking away at the distance after prolonged use of a digital display.[7] Ocular symptoms after sustained computer use, which are part of the computer vision syndrome, are significantly worse than those reported after using hard copy materials under similar viewing conditions, specifically blurred near vision due to tear film disruption.[8] Ranasinghe et al. estimated that approximately 60 million people have signs and symptoms of computer vision syndrome.[9] Electronic displays, including laptops, tablets, and smartphones, have dramatically altered the way information is accessed and become significant factors in human daily life compared to hard-copy versions. Therefore, this study was designed to investigate the hypothesis that screen based devices induce greater changes to tear stability and volume than traditional hard copy reading tasks.

METHODS

Study population

This study included 30 visually-normal young adult participants who met the inclusion criteria. Based on the variability of NIBUT and strip meniscometry, a sample size of 30 participants was able to detect a 3.5s difference in NIBUT and a 0.6mm difference in SM with a statistical power of 95%, taking p as <0.05 (G*Power v3.1.9.6, Universitat Dusseldorf, Germany).[10, 11] After a complete explanation of the study, written informed consent was obtained from each participant. All steps of this study adhered to the tenets of the Declaration of Helsinki and it also was approved by the local Ethics Committee (Code: IR.MUMS.REC.1397.192).

Included participants had corrected distance and near visual acuity of at least 6/6 in each eye, no history of ocular and systemic diseases, no history of contact lens wearing, no pregnancy at the time of assessments, no use of ocular drops and systemic drugs influencing the tear film status. Participants were neither diagnosed nor reported any symptoms of dry eye (Persian version of the ocular surface disease index (OSDI) questionnaire less than 13,[12] and non-invasive tear breakup time (NITBUT) > 10 sec).[13] Participants with amblyopia, strabismus, esophoria or exophoria more than 10 prism diopters at near, near point of convergence greater than 5 cm, decreased accommodation amplitude at least 2 diopters below the lowest expected amplitude based on the Hofstetter's formula,[12] oculomotor abnormalities, and self-reported dyslexia or other forms of reading disability were also excluded from the study.[14]

Baseline and reading conditions

Participants read a specific text silently on the laptop computer screen (Acer TravelMate P643 with a 13-inch flat-display, with a resolution of 768 x 1366 pixels and screen refresh rate 60 Hertz) and an identical printed hard copy page. Both tasks were presented at a viewing distance of 40 cm for a continuous 30-minute period. In the computer reading condition, the participant scrolled through the text whereas for the hard copy condition, participant turned the pages over when each was completed. The text characteristics were single-spaced text, with font color, style, and size specified as black B Lotus 14-point and contrast of approximately 80%. Similar passages, matched for text size, font and contrast, were used in all sessions while participants wore their habitual spectacle refractive correction. Reading materials for both conditions were black letters on a white background without images, plots, and pictures. The laptop screen was adjusted so that approximately seventy-five percent of the screen was below the participant's line of sight in the primary position of gaze and the screen's surface was approximately parallel to the participant's face plane. To simulate a similar reading conditions for hard-copy material, it was taped to a reading stand with similar angular setting. Lighting conditions were adjusted to provide a target luminance of approximately 15 cd/m^2 for hard copy material and laptop computer screen. Room temperature was maintained between 22–24˚C and room humidity was kept between 40-50%. The right eye data were used for analysis.

Each of the two tests used in this study (NITBUT and strip meniscometry tube tests) was performed three times: after 30 minutes of rest (during the rest time, the participants were asked to relax and not to read anything or use a smartphone), after 30 minutes reading a hard-copied text, and after 30 minutes of reading a text presented on a laptop computer screen in random order. Sessions were separated by at least 24 hours. All measurements were carried out by an examiner masked to the participant's task between 9 am and 12 noon.

Procedure

NITBUT was measured using a keratometer (Topcon keratometer, OM-4, Japan), the participants sat in front of the keratometer and were asked to look straight ahead and keep their eyes open as long as possible after several complete blinks. The average of three intervals between the last blink up to the first appearance of distortion or discontinuity of mires was recorded in seconds as NITBUT.

Meniscometry was performed using strip meniscometry Tube (Echo Electricity Co., Ltd., Japan). The tip of the tear-absorbing strip was immersed into the tear meniscus in the lateral lower lid without touching the cornea, eyelid or conjunctiva for 5 seconds. The length of the blue dye column in the central ditch (or the tear-absorbing length) was measured and recorded in millimeters.[15]

Statistical analysis

Data was analyzed in SPSS.16. The normality of data was assessed using the Kolmogorov-Smirnov test. As the data were not normally distributed, median and interquartile range (IQR) was used to describe the variables. The Friedman test was used to compare the mean NITBUT and strip meniscometry tube tests in different sessions, between the two reading conditions (hard-copy and laptop computer screen) and their comparisons with data obtained while participants were resting. Pairwise comparisons were performed using the Dunn-Bonferroni post hoc test. The differences between baseline and post reading tasks were non-normally distributed. The mean difference of the strip meniscometry tube and NITBUT tests while reading the text from a hardcopy and laptop computer screen compared to the baseline was analyzed using the Mann-Whitney U test and their correlation was evaluated using the Spearman correlation test. A P-value less than 0.05 was considered significant statistically.

RESULTS

Of the 30 participants in this study, 18 (60%) were female. The participants' mean age was 22.9±2.4 years with a range of 20 to 30 years. There was no statistically significant difference in the mean age between the two sexes (P= 0.743).

The Median and IQR of tear film assessment at the baseline and after reading the text presented in hard-copy and on the laptop computer screen are displayed in Table 1.

Table1:

Assessing the quantity of tear film after hard-copy reading and reading on the laptop computer screen showed that the median of NITBUT decreased by 3.0 seconds following hard-copy reading and 6.0 seconds after reading on the laptop computer screen compared to the baseline evaluation. There was also a median decrease of approximately 1.7 mm and 1.7 mm using the strip meniscometry tube test compared to the baseline evaluation, respectively.

Comparison of the repeated NITBUT and strip meniscometry tube measures before and after reading using Friedman's test showed a significant difference in different statutes (baseline evaluation, after hard-copy reading and after reading on the laptop computer screen, $P < 0.001$). Dunn-Bonferroni post hoc tests showed a significant difference between all pairs for the NITBUT test and between all pairs except after reading the hard-copy and computer screen ($P = 0.085$) for the strip meniscometry tube test.

The mean difference in the result of the strip meniscometry tube and NITBUT tests when reading a text from a hardcopy and laptop computer screen from baseline and their correlations in young adults with healthy eyes are given in Table 2.

Table 2:

There was a statistically significant difference in the mean changes of strip meniscometry tube ($P = 0.015$) and NITBUT results ($P < 0.001$) between the two reading conditions. Changes relative to baseline, in both tear quality and quantity aspects were more considerable after reading on a laptop computer screen. In addition, for tear film quantity assessed with strip meniscometry and quality shown by NITBUT , there were statistically significant correlations between the baseline and post task data for both reading conditions (strip meniscometry $P < 0.001$, NITBUT $P < 0.001$).

DISCUSSION

This study investigated the changes in the tear film using non-invasive tear break-up time and strip meniscometry tube test following a sustained 30 minutes reading from a laptop computer screen and hard copy text. The findings showed a significant decrease in the NITBUT and strip meniscometry tube compared to their baseline measurements, with a lower NITBUT after reading on the laptop computer screen compared to hard-copy, while the tear volume was not significantly different between two reading conditions. Other studies have previously examined the difference between reading from screens versus hard copy, but the recent Tear Film and Ocular Surface Society Lifestyle report on the impact of the digital environment on the ocular surface identified that the results were variable and further information was needed on the time-course of changes within a digital environment.[16]

These findings demonstrated that silent reading on a hard-copy or laptop for as little as 30 minutes leads to considerable alterations in the homeostasis of the tear film on the ocular surface in healthy adults without notable ocular surface disorders. One of the reasons for these changes may be the reduction in spontaneous eye blink rate previously reported to accompany a focused and concentrated visual task, or when reading, in both conditions.[1, 17-20]

The faster break-up of the tear film following reading on the laptop compared to hard-copy could also be due to an increase in the percentage of incomplete blinks that occur when reading from electronic devices.[1, 21] Cho and colleagues found a statistically higher level of incomplete blinking during computer activity compared with a similar task using printed materials in equivalent conditions.[19] The deterioration of dry eye symptoms following sustained computer use over hard copy reading in similar viewing conditions supports the results of the current study.[22, 23]

The observed changes in tear volume following a reading task are in line with a previous study, although they used the Schirmer test to assess the tear film quantity.[18] In contrast with the present study, Choi and colleagues found no significant change in the Schirmer test value and tear meniscus height after smartphone or computer display use,[24] perhaps due to the variability of these tests of tear film volume. A previous study reported that there is a high variability in Schirmer test results.

Feldman F, Wood MM. Evaluation of the Schirmer tear test. Can J Ophthalmol. 1979 Oct;14(4):257-9. PMID: 550920.

On the other hand, one study mentioned good in vivo reproducibility of the strip meniscometry tube.

Dogru M, Ishida K, Matsumoto Y, Goto E, Ishioka M, Kojima T, Goto T, Saeki M, Tsubota K. Strip meniscometry: a new and simple method of tear meniscus evaluation. Invest Ophthalmol Vis Sci. 2006 May;47(5):1895-901. doi: 10.1167/iovs.05-0802. PMID: 16638996.

The reduction in tear stability and volume was found to be proportional to the starting tear stability and volume respectively, which suggests more of an evaporative effect than a change in drainage patency. It also suggests that a more homeostatic tear film will be more robust to environmental challenges such as prolonged reading, reducing the likelihood of ocular discomfort and asthenopia. These findings are in agreement with a recent study that assessed the effects of prolonged reading on the tear film status and ocular comfort.[18]

Finding no significant correlation between the strip meniscometry tube and NITBUT results at different states is consistent with the results of previous studies which reported no correlation between the Schirmer with the NITBUT tests.[25, 26] In addition, Nichols and colleagues mentioned that there are often conflicting findings between various dry eye diagnostic tests with a poor agreement between them.[27]

One of the limitations of the current study was the lack of an objective assessment of blink rate, so that this could be directly related to the way in which different reading conditions influenced the tear film and ocular surface status. A decrease in the blink rate, or incomplete blinking during near work have been reported in previous studies.[1, 19, 21, 28, 29] Another weakness is the lack of evaluation of the ocular symptoms of discomfort after the reading hard-copy and on the laptop computer screen, as worsening of the asthenopia and ocular dryness after prolonged reading was reported previously.[18, 24, 30] Another limitation was the lack of exact matching of luminance as the light flux density at the cornea for the two reading conditions.

CONCLUSION

The present study showed that both 30-minute hard-copy reading and on a computer screen leads to tear film instability in terms of the tear film quality and quantity assessed using the NITBUT and the strip meniscometry tube test, respectively. Additionally, reading on the computer screen has a greater impact on the tear film break-up time compared to hard-copy reading, while these two types of reading had the same effect on the assessed tear volume.

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Table 1: Median and interquartile range (IQR) of tear film quality and quantity assessed using the strip meniscometry (SM) and noninvasive tear break-up time (NITBUT) at baseline and during reading text from a hardcopy and laptop computer screen in young adults with healthy eyes. (n= 30)

Variables	**Median [IQR]**			**Friedman Test [Pairwise Comparisons]**
	Baseline (1)	**Hard copy (2)**	**Laptop computer Screen (3)**	
NITBUT (sec)	13.0 [12 to 16.5]	10.0 [8.7 to 11.0]	7.0 [5.7 to 9.0]	($X^2(2) = 59.513$, P< 0.001) [1,2: <0.001, 1, 3: <0.001, 2, 3: 0.001]
SM tube (mm)	6.7 [6.0 to 9.0]	5.0 [4.0 to 7.0]	5.0 [4.0 to 5.0]	($X^2(2) = 51.282$, P< 0.001) [1,2: <0.001, 1, 3: <0.001, 2, 3: 0.085]

(SM: Strip meniscometry; NITBUT: Noninvasive tear break-up time; CI: Confidence interval)

Table 2: Changes in the results of strip meniscometry (SM) and noninvasive tear break-up time (NITBUT) tests during reading text from a hardcopy and laptop computer screen compared to the baseline and their correlations in young adults with healthy eyes. (n= 30)

Variables		**Mean Difference±SD (95% CI)**	**P-value (Mann-Whitney U test)**	**Spearman Correlation (r_s, P-value)**
Change in SM (mm)	**Hard copy**	-1.6±1.0 (-1.9 to -1.2)	0.015	0.563, <0.001
	Laptop computer screen	-2.6±1.6 (-3.2 to -2.0)		
Change in NITBUT (sec)	**Hard copy**	-4.6±2.4 (-5.5 to -3.7)	<0.001	0.765, <0.001
	Laptop computer screen	-7.4±3.4 (-8.6 to -6.1)		

(SM: Strip meniscometry; NITBUT: Noninvasive tear break-up time)