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ORIGINAL ARTICLE

Young non-VDU users are more susceptible to ocular functions changes with sustained VDU nearwork

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KEYWORDS
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Abstract
Purpose: This study investigates the change in ocular functions among young schoolchildren following nearwork with and without visual display units (VDU).
Methods: Thirty-one young schoolchildren played computer game (VDU work) and paper game (non-VDU work) continuously for 2 h at 40 cm. Non-invasive tear break up time (NIBUT), blinking rate (BR) and palpebral aperture size (AS) were measured before and after VDU work and non-VDU work. Reading for NIBUT, BR and AS were normalized by converting into $\log_{10}$ unit.
Results: MANCOVA analysis shows that logNIBUT is significantly reduced after both nearwork ($F_{1,49} = 58.10$, $p < 0.01$) but not for log BR and log AS ($p > 0.01$). Pairwise comparison shows that modes of nearwork produce significant different effect in post-task log BR ($F_{1,53} = 7.13$, $p = 0.01$) and log AS ($F_{1,53} = 11.00$, $p < 0.01$). VDU work produces lower BR and larger AS while Non-VDU work does not change the BR but is associated to a smaller AS.
Conclusions: Sustained 2-h VDU work and non-VDU work produces significant reduction in NIBUT measurements. Modes of nearwork differently change the post-task BR and AS. Young schoolchildren are more susceptible to VDU nearwork effect.

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PALABRAS CLAVE
Jóvenes escolares;
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Pantalla de visualización;
Lagrimal;
Ocular

Los jóvenes que no utilizan pantallas de visualización son más susceptibles a los cambios de las funciones oculares tras visión de cerca prolongada de pantallas de visualización

Resumen
Objetivo: en este estudio se investiga el cambio de las funciones oculares en jóvenes escolares después de la visión de cerca tras y sin pantallas de visualización.
Métodos: 31 jóvenes jugaron con un juego de ordenador (visión de pantalla) y un juego de mesa (visión sin pantalla) de forma continua durante 2 horas a 40 cm. Antes y después de la visión con pantalla y sin pantalla se midió el tiempo de ruptura lagrimal no invasivo (NIBUT), la velocidad de parpadeo (VP) y el tamaño de la apertura palpebral (TAP). Los valores de NIBUT, VP y TAP se normalizaron mediante la conversión a unidad $\log_{10}$.
Resultados: el análisis MANCOVA muestra que logNIBUT se reduce de manera significativa con ambas situaciones de visión de cerca ($F_{1,49} = 58{,}10$, $p < 0{,}01$), pero no sucede lo mismo con logVP y logTAP ($p > 0{,}01$). La comparación por pares muestra que los modos de visión de cerca producen un efecto significativamente diferente en logVP ($F_{1,53} = 7{,}13$, $p = 0{,}01$) y logTAP ($F_{1,53} = 11{,}00$, $p < 0{,}01$) posteriores a la tarea. La visión de cerca de pantallas de visualización produce una VP menor y un TAP mayor, mientras la visión de cerca sin pantalla no cambia la VP y produce un TAP menor.
Conclusiones: la visión de cerca prolongada con pantallas y sin pantallas durante 2 horas produce una reducción significativa del valor de NIBUT. Los modos de visión de cerca cambian de diferente manera la VP y el TAP posteriores a la tarea. Los jóvenes escolares son más susceptibles al efecto de la visión de cerca con pantallas de visualización.

Introduction

The quality of the precorneal tear film (stability and adequate production) plays an important role to ensure the maintenance of the normal optical integrity. Visual and ocular symptoms experienced by the visual display units (VDU) operators have been reported to associate with changes in the stability of preocular tear film.[1–9] Symptomatic VDU users who suffer from dry eye problems and ocular discomfort have showed reduced blinking rate (BR).[4,5,7–9] The reduction in the BR, tear break up time (TBUT) and variation in the precorneal tear film accompanying with lacrimal evaporation,[10,11] are suggested to be due to abnormalities created in the oily layer of the precorneal tear film as a result of accumulative VDU operation.[6]

In well controlled laboratory set-up, both groups of subjects with dry eye symptom and normal healthy eyes showed significantly reduced BR while playing computer games and letter tracking task in comparison to other tasks such as watching movies and primary gaze.[2] Assessment of tear film stability using retroillumination with slit-lamp biomicroscope revealed that the increased instability during computer game playing was due to reduced BR and frequent incomplete blinking pattern during the task.[2,3]

Recent work by Nakamura et al.,[4] examined the association between duration of VDU related work and changes in ocular tear functions (precorneal tear stability, lipid layer status and tear secretion) in 1025 office VDU workers. Nakamura study found that the number of years working with VDU and daily VDU using time significantly affected the stability of precorneal tear film (reduced tear break up time, TBUT) and tear secretion. Production of tear was significantly reduced for those workers who worked with VDU for the past 8–12 years with averaged daily VDU using time of 6–8 h in comparison to those who only used VDU for less than 4 years and averaged daily VDU using time of 2 h or less. Lacrimal gland hypofunction was postulated as the cause underlined the precorneal tear film instability and lower tear secretion following VDU work.[4]

The ocular function change is well documented among the adult VDU users but not with young schoolchildren population. Greater change in visual function has been reported among young children after their enrollment into elementary educational system.[12] If change in ocular function is capable of creating visual and ocular discomfort among the children while working with VDU, this may interrupt their learning process as education system nowadays poses greater demand on information searching with VDU. Herein, this study aims to investigate the change in ocular functions after sustained nearwork with and without VDU in a group of inexperienced young schoolchildren.

Materials and methods

Thirty-one 7-year-old, first-primary schoolchildren (15 male and 16 female) with parental consent participated in this study through random sampling. All subjects were emmetropic or hyperopic with spherical component of their refractive error ranging between −0.25D and +1.25D, astigmatism less than −1.00DC, anisometropia less than 1.00D and no history of ocular pathology or systemic diseases based on questionnaire distributed to their parents. All subjects had monocular and binocular corrected visual acuity of 6/6

or better. Subjects recruited for this study were non-VDU users. Based on the questionnaires, all subjects spent less than 5 h per week working on the VDU, at least for the last year. According to classification by Saw et al.,[13] only those who spent at least 5 h on VDU display every day were categorized as VDU users. This study adhered to the ethical standards of the Helsinki Declaration and had approval from the Ethic Committee of the University.

This crossover design study compared the effect of nearwork with and without VDU on ocular functions which included the measurement of non-invasive tear break up time (NIBUT), blinking rate (BR) and palpebral aperture size (AS). Same subjects worked as the experimental group as well as the control group. The illumination of the experimental room was fixed between 300 lux and 380 lux (with Topcon Luxmeter). Illumination on VDU display and print out copy was also monitored with luxmeter every time before starting the nearwork session and before termination of the nearwork session. Nearwork with and without VDU were carried out on two separate days with a minimum rest of 72 h between the two tests. Nearwork sessions were implemented between 12:30 p.m. and 5:30 p.m. Room temperature ranged from 22 °C to 27 °C throughout the study.

Subject was assigned to play computer games (VDU work) and visual searching task with printed copy on paper (non-VDU work) in random sequence. Computer game was displayed on desktop (NEC Powermate ML5). The type of display used in this study was the conventional desktop display which has convex screen. The illumination of VDU display ranged between 300 lux and 380 lux, while the contrast and brightness of the display were fixed at 80% and 90% respectively to produce luminance between 66 cd/m^2 and 70 cd/m^2 (Topcon Luminance meter BM-5). Games such as Virtual Cops 2, Tetris and Bomber Man 2 with great visual demand and visual searching activities were used as VDU related nearwork to increase the demand of visual concentration. Meanwhile, non-VDU work involved visual searching and drawing task, such as maze, searching words from a pool of alphabets, searching differences in two almost identical pictures, joining dots, drawing and matching pictures. Non-VDU work was presented on black and white print out with the size of print ranging from 4 mm to 6 mm. Illumination on the print out copies was between 300 lux and 380 lux, which also produced an average luminance ranging between 60 cd/m^2 and 70 cd/m^2. Subjects were encouraged to compete with each other during the task. Both modes of nearwork were carried out in the same experimental room to avoid variation in room illumination and room setup.

The non-invasive tear break up time (NIBUT) was measured with Tearscope Plus (Keeler Ltd., UK).[14] The finest grid pattern was mounted onto the Tearscope. Subject was instructed to blink for a few times and opened his eyes as wide as possible when examiner counted to three. The duration of time as subject opened his eyes till any distortion observed in the grid pattern was recorded as the NIBUT. Subject was allowed to blink for a few seconds before the next NIBUT was measured. A number of five NIBUT readings were taken and the three closest readings were averaged to obtain the mean NIBUT, recorded in seconds (s). Subject who blinked before dry spots or distortion was observed and was instructed to close his eyes and blink for a few seconds. Subject was allowed to rest to avoid reflex tearing, which might affect the NIBUT reading. The BR and AS were measured while subject was performing the nearwork. A video camera (Sony TRV-18E) was attached to tripod, fixed at one meter height and one meter away from subject, and at an angle 45° from subject.[15] Subjects were encouraged to concentrate at the nearwork and conversation was not allowed during the task. The BR was recorded for 5 min within the first 30 min just after nearwork begun. This was followed by AS measurement. The video camera was shifted to an angle of 90° to subject's side and AS was recorded for one minute. Measurements of BR and AS were repeated 30 min before termination of nearwork session. BR was calculated from the video recording play back and recorded in numbers of blink per minute. In video recording playback, a complete eye blink or partial eye blink (more than ¾ of the exposed cornea area) was considered as one eye blink.[14] Three AS readings were calculated from video recording play back within the 1 min recording time (at 5-s, 25-s and 55-s), and these readings were averaged and recorded in millimeters (mm).

Normality test showed that the NIBUT, BR and AS readings were not normally distributed (Komogorov–Smirnov, $p < 0.05$). In order to carry out variance analysis, readings were normalized by transforming the data into $\log_{10}$ unit. Both pre-task readings in log NIBUT, log BR and log AS were compared with paired t test to determine whether there was pre-existing difference in the measurement. The effect of nearwork on log NIBUT, log BR and log AS was determined using the MANCOVA test with Bonferroni adjustment. The pre-task readings were the covariates, post-task readings were the dependent variables and the modes of nearwork were taken as the independent variable. P value was considered significant at level 0.01 with Bonferroni adjustment. Power of analysis for all dependent variables tested in present study was ranged from 80% to 97%.

Results

Comparison of the pre-task readings prior to VDU work and non-VDU work demonstrates that there is a significant difference in log AS ($t = 10.36$, $p < 0.01$) whereby subjects always show greater AS with VDU work. The smaller vertical tilted gaze direction adopted by the young schoolchildren while performing the VDU work produces greater AS. The reverse happens while the same children work with non-VDU work. Both log NIBUT and log BR measurements are not significantly different before the nearwork sessions were carried out ($p > 0.01$). The measurement of log NIBUT and log BR are reliable and repeatable in this study.

MANCOVA analysis with pairwise comparison shows that the post-task log NIBUT reading is significantly reduced in comparison to pre-task readings ($F_{1,49} = 58.10$, $p < 0.01$). When the pre and post-task log NIBUT reading from both nearwork are compared with paired t test, VDU work produces significant reduction in post-task log NIBUT, equivalent to a reduction of -3.71 ± 4.50 s in NIBUT reading (Fig. 1). For the non-VDU work, post-task NIBUT reading reduces by -2.92 ± 6.84 s, which is not significantly different from pre-task reading (Fig. 1). For the BR, post-task log BR is not significantly different from pre-task reading ($F_{1,53} = 6.07$, $p = 0.02$) after Bonferroni adjustment but modes of

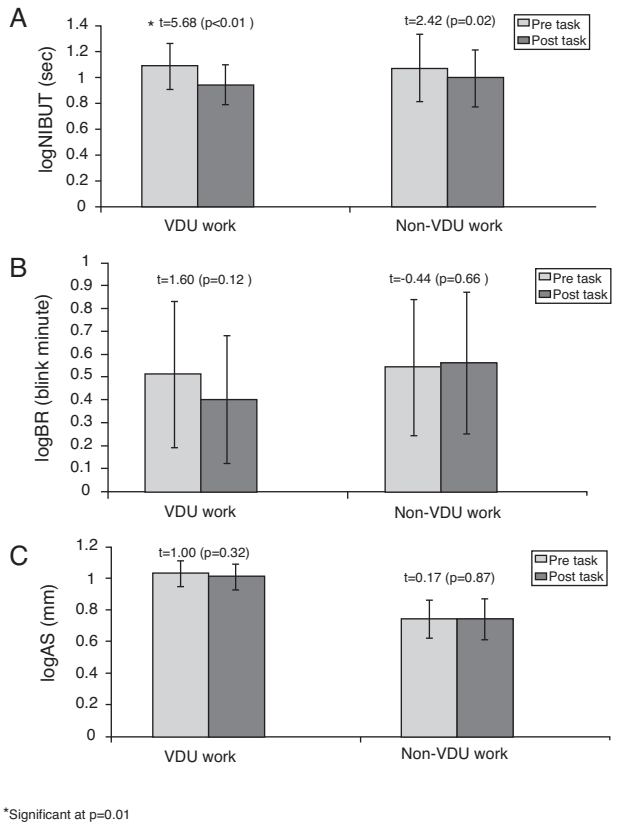

Figure 1 Comparison of the pre-task reading and post-task reading for log NIBUT log BR and log AS in the emmetropic children after nearwork with and without VDU.

nearwork produce statistically significant different pattern in log BR ($F_{1,53} = 7.13$, $p = 0.01$) with lower log BR values after the VDU work in comparison to non-VDU work. Similarly, post-task logAS reading is not significantly different from pre-task reading ($F_{1,53} = 6.24$, $p = 0.02$). However, modes of nearwork produce significant different effect in post-task log AS ($F_{1,53} = 11.00$, $p < 0.01$) with slight reduced AS after VDU work but not with non-VDU work (Fig. 1).

Discussion

Two hours of sustained nearwork with and without VDU produces significant reduction in NIBUT. Although both nearworks do not produce significant changes in BR and AS, but data from present study demonstrate that both modes of nearwork induce significant different effect in BR and AS. Sustained VDU work produces lowers BR and children reduce the AS during the course of VDU nearwork. In contrast, greater BR is observed in the children during Non-VDU work with no change in AS.

Reduction in NIBUT reading after nearwork with VDU is consistent with previous reports.[2,3,6] Sustained fixation on VDU displays has been suggested to associate with significant reduction in BR,[5,7,8,16,17] which subsequently reduces the stability of preocular tear film or the TBUT.[2,3,10,18] High cognitive demand during nearwork is capable to suppress the BR in the young schoolchildren who are non-VDU users.[19–21]

In the present study, same group of children play the computer game and paper game with exactly similar work environment (same luminance level, working distance and same work duration). However, there is a distinct difference in BR and AS with different modes of nearwork. These discrepancies can be explained by difference in the displays' physical characteristics. Visibility of the fixating object during the course of nearwork was reported to influence the cognitive demand level.[16,17,22,23] When subjects looked at small font size or blurred object, continuous concentration required to fixate at the object reduced the BR in order to avoid interruption on the visual input during the blinking action.[6,19–21] This would reduce the stability of precorneal tear film and increase the ocular discomfort.[10,22] Later work by Tsubota et al.,[17] noted a significant increment in BR and stability of precorneal tear film when reflection of the display was removed with specially designed anti-reflective film. Such improvement in BR and precorneal tear film stability was also observed when the same anti-reflection film was applied to portable DVD player screen and handheld video game.[16] Better visibility in VDU display had been proposed to lessen the cognitive demand level, which reduced inhibition on BR. As a result, less evaporation from the precorneal tear film produced more stable precorneal tear film. Computer display used in present study is the most common form found in local primary schools. It is readily known that presence of reflection gives rise to Mandelbaum effect in the convex screen of the VDU display. Mandelbaum effect produces confusion in accommodative effort as a result of variation in the vergence of fixation target.[24] Reflection from the surrounding light source may also cast shadow onto the VDU display which consequently reduces the visibility of the game subjects are fixating at. Furthermore, encouragement to compete with each other during task may require greater cognitive demand. These factors further reduce the NIBUT reading with VDU nearwork, whereas, high contrast and mate surface printed hardcopy presents better object visibility. This may have lessened the cognitive demand within non-VDU work. Therefore a significant reduced NIBUT but at a lesser extent is found after non-VDU work.

Work posture adopted by subjects during nearwork may also be responsible for the outcome of the present study.[5,8–10,25,26] Greater vertical inclination gaze direction while performing non-VDU work reduces the size of ocular area exposed to air, and thus reduces the evaporation rate of the preocular tear film.[10,11] Therefore, a smaller AS with increased vertical inclination gaze direction allows thicker lipid layer covering the ocular exposed area, leading to a lesser evaporation rate from the aqueous layer. So, a lesser BR would be noted with smaller AS. In contrast, a lower vertical inclination gaze direction during VDU work would have produced larger AS and the reverse is expected. In this study, mean vertical inclination gaze direction during VDU work and non-VDU work is $9.8 \pm 5.6^{\circ}$ and $30.3 \pm 8.5^{\circ}$, respectively. Our workstation set-up produces AS of 10.5 ± 1.93 mm for VDU work and 5.78 ± 1.60 mm for non-VDU work, which is equivalent to ocular exposed area of 2.81 cm^2 and 1.37 cm^2, respectively (applying formula suggested by Sotoyama et al.,[11]). Larger ocular exposed area during VDU work in present study may increase the evaporation rate of the preocular tear film which reduces the stability of preocular tear film. A compensatory increased BR

Table 1 Mean NIBUT, BR and AS for both VDU work and non-VDU work in pre-task and post-task measurement.

	VDU work		Non-VDU work	
	Pre-task (mean ± SD)	Post-task (mean ± SD)	Pre-task (mean ± SD)	Post-task (mean ± SD)
NIBUT (s)	12.94 ± 5.68	9.23 ± 0.88	13.98 ± 9.51	11.07 ± 5.88
BR (number of blink per min)	4.23 ± 3.68	3.06 ± 1.98	4.25 ± 2.71	4.67 ± 3.72
AS (mm)	10.83 ± 1.87	10.50 ± 1.93	5.83 ± 1.71	5.78 ± 1.60

SD: standard deviation; NIBUT: non-invasive tear break up time; BR: blinking rate; AS: palpebral aperture size.

would be expected to overcome the unstable tear film and to avoid formation of dry sport on ocular surface.[25] However, we do not observe this compensatory reaction during VDU work. In contrast, there was a decreased BR and an insignificant reduced AS during the end session of VDU work. We believe high degree of cognitive demand may override the blinking action to allow continuous visual input processing during the VDU game. In order to avoid formation of dry spot and ocular discomfort as a result of less BR and larger ocular exposed area during VDU work, subjects voluntarily squint their eyelid (smaller AS), probably to increase the tear thickness and to reduce the evaporation rate of the preocular tear film. However, voluntary squinting of the eyelid had been speculated to cause certain amount of tear loss through the drainage system,[27] thus a reduced NIBUT with VDU work. Smaller ocular exposed area during non-VDU work produces a smaller change in NIBUT coupled with compensatory reaction of increasing the BR at the end of nearwork session.

Our study demonstrates that 2 h of continuous VDU work and non-VDU work produce significant change in the stability of preocular tear film in young schoolchildren who are non-VDU users. However, our subjects are more susceptible under VDU nearwork conditions as a result of greater reduction in BR and larger AS. As short-term exposure to VDU work is capable of changing the stability of tear, it is reasonable to predict that a greater change would be expected if VDU work is carried out in long-term. Concerning the ocular symptom reported in adult VDU users,[1] there is a need to determine a proper workstation design for young schoolchildren in order to minimize change in ocular functions. Increasing number of hours spent on VDU in primary schoolchildren nowadays suggests that a prompt investigation is required.

Conclusion

Sustained 2 h VDU work and non-VDU work produce significant reduction in the stability of preocular tear film (NIBUT reading). Modes of nearwork produce significant different effect on BR and AS. Young schoolchildren who are non-VDU users are more susceptible to VDU nearwork effect (Table 1).

Competing interest

None.

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