Impact of Prolonged Exposure to Video Display Terminals on Macular Pigment Optical Density in Young Adult Filipinos

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ABSTRACT

Objective: This study assessed the correlation of macular pigment optical density (MPOD) and varying levels of exposure to video display terminals (VDT) among young adult Filipinos.

Methods: This cross-sectional, analytical, single-center study compared the MPOD, measured using the Zeiss VISUCAM 500, between two groups of individuals aged 20 to 35 years old with differing VDT exposure. The more exposed group consisted of individuals who spent at least 8 hours per day on VDTs for the past 1 year, while the less exposed group spent less than 6 hours per day. Student's *t*-test and chi-square test were used to compare the two groups, while Pearson's *r* coefficient was utilized to determine the relationship between MPOD and VDT exposure.

Results: A total of 80 individuals (40 in each group) were included in the study. Both groups had similar profiles, except for refractive errors, which were significantly higher in the prolonged VDT exposure group ($p = 0.02$). The prolonged exposure group averaged 10 hours of VDT use per day, compared to 3 hours in the low VDT exposure group. The MPOD level, particularly the maximum optical density (Max OD), was significantly lower in the prolonged VDT exposure group (0.2034 DU) compared to the low VDT exposure group (0.2467 DU) ($p = 0.0051$). A negative weak correlation was observed between the VDT exposure hours and MPOD levels (Max OD $r = –0.387$, $p = 0.0005$).

Conclusion: This study found a weak but significant negative correlation between prolonged VDT exposure and lower MPOD levels, suggesting that extended screen time may contribute to reduced macular pigment density. While the correlation was weak ($r = –0.387$), these findings underscore the potential risk of diminished macular health with increased VDT use. The results highlight the importance of promoting protective strategies, such as reducing screen time and encouraging dietary or lifestyle changes that support eye health, especially among individuals with high VDT exposure.

Keywords: macular pigment optical density, MPOD, video display terminal, VDT, digital device, Filipino

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Prolonged exposure to computer monitors or video display terminals (VDT) has been associated with various visual complaints, such as asthenopia and dry eyes.[1] According to Parihar *et al.*, individuals working more than 4 hours daily with VDTs are significantly more likely to experience asthenopia, and working over 8 hours per day is considered a risk factor for VDT-related dry eyes.[1]

Compared to older cathode ray tubes displays, most computer screens today emit more blue light.[2] Blue light, which has the shortest wavelength and highest energy in the visible electromagnetic spectrum, has been reported to pose potential hazards to the retina.[3] Several *in vitro* and animal studies have highlighted the detrimental effects of short-wavelength light. In the study of Kuse *et al.* where murine cone photoreceptor-derived cells were exposed to blue, white, or green light emitting diode (LED) light, blue LED light significantly increased the production of reactive oxygen species (ROS), altered protein expression level, and induced the aggregation of short-wavelength opsins, resulting in severe cell damage.[4] Shang *et al.* found that rats exposed to blue (460 nm), green (530 nm), and red (620 nm) LEDs experienced most functional damage from the blue light, when assessed by electroretinogram results. Histological examination revealed apoptosis and necrosis of photoreceptors and retinal pigment epithelium (RPE), indicating that blue LED light induced more photochemical injury compared to green or red LED.[5] In a similar study by Jaadane *et al.*, blue light exposure in animals resulted in photoreceptor loss and triggered cell death pathways, including caspase-independent apoptosis, necroptosis, and necrosis, further confirming the potential risks of blue light to retinal health.[6]

Macular pigments, primarily carotenoids, are essential compounds that humans cannot synthesize. For macular pigments, humans rely entirely on dietary sources such as fruits, vegetables, and egg yolks.[7] There are two major macular pigments in the human eye, lutein and zeaxanthin, which are densely concentrated in the Henle fibers and inner plexiform layer of the fovea. They protect the retina by acting as optical filters for short wavelength blue light, with specific absorption between 400 and 500 nm, particularly at 444 nm.[7] Macular pigments also provide anti-oxidant protection against ROS. They quench the triplet state of photosensitizers, neutralize singlet oxygen, react with free radicals, and act as chain-breaking anti-oxidants to slow peroxidation of membrane phospholipids.[7] The retina is especially vulnerable to oxidative stress for two reasons: it is exposed to light and high oxygen levels due to its rich vascular network, creating an ideal environment for ROS generation, and it contains high levels of polyunsaturated fatty acids, which are easily oxidized by ROS.[7]

Currently, the most common methods for measuring macular pigment optical density (MPOD) include heterochromatic flicker photometry (e.g., Macuscope) and reflectometry (Zeiss VISUCAM).[8] In healthy subjects, MPOD values are typically highest near the foveal center and decrease by a factor of 100 within a few millimeters of eccentricity.[9] The MPOD values tend to increase during adulthood, peaking at 45-50 years, followed by a gradual decline after the age of 60.[9] Evidence supports the protective role of higher MPOD values. Recent studies indicate that individuals with degenerative macular conditions, such as age-related macular degeneration (AMD), have significantly lower MPOD levels. Conversely, higher MPOD density has been associated with improved visual performance, particularly visual acuity.[10]

With the increasing use of digital devices, eye problems such as asthenopia and dry eyes are becoming more prevalent. However, the long-term effects on the retina remains a topic of debate. This study aimed to compare the MPOD levels – measured using the VISUCAM 500 fundus camera – between individuals aged 20 to 35 years with prolonged VDT exposure, defined as more than 8 hours per day for at least a year, and individuals of the same age range with low VDT exposure. Additionally, we aimed to detect if there was any correlation between the duration of VDT exposure and MPOD levels.

METHODS

This was a cross-sectional, analytical, single-center study. The study was conducted at a tertiary government hospital in Metro Manila, Philippines, from January to December 2019. The study adhered to the tenets of the Declaration of Helsinki and

received approval from the local Institutional Review Board. Informed consent was obtained from each study participant.

The study participants were aged 20 to 35 years, with best-corrected visual acuity (BCVA) of 20/20, a refraction of less than ± 5.00 diopters (D) sphere and ± 3.00 D cylinder, and a minimum scotopic pupil size of 4 mm. Individuals with ocular media opacity, retina disorders, previous ocular surgery, history of smoking, intake of supplements containing lutein and zeaxanthin, use of blue-blocking glasses or display monitor filters, and pregnancy were excluded. These selection criteria were based on the study by Creuzot-Garcher *et al.* on MPOD.[8]

Convenience sampling was employed to recruit the study participants. Sample size calculation was based on a study on MPOD levels among Filipino adults by Mupas *et al.*[11] A minimum of 36 participants per group was required to achieve a 95% confidence level and 80% power of the test with a medium effect size ($d = 0.60$) for comparing continuous variables.

All participants completed a self-administered questionnaire in English which had been validated by a previous trial on 20 individuals. The questionnaire collected information on demographics, medical and ocular history, smoking history, intake of lutein and/or zeaxanthin supplements, diet (specifically lutein-rich), VDT or digital device use, and the use of blue-blocking filters. Exposure to VDTs, including cellphones, tablets, and computers, was assessed based on recall, with participants estimating their average cumulative daily usage over the past year.

After completing the questionnaire and undergoing an interview to verify their answers, eligible participants underwent a complete ophthalmologic evaluation by a single ophthalmologist. The evaluation included visual acuity assessment, refraction, pupil size measurement, intraocular pressure measurement, slit-lamp biomicroscopy, and posterior segment examination.

Based on their responses to the questionnaire, study participants were classified into two groups for comparison. The first group, referred to as the "prolonged VDT exposure group", consisted of individuals who spent at least 8 hours per day in front of a VDT over the past year. The second group, the "low VDT exposure group," included individuals whose VDT exposure did not exceed 6 hours per day.

When both eyes of a participant satisfied the inclusion criteria, only one eye was chosen randomly for MPOD analysis. When only one eye satisfied the inclusion criteria, that eye was included in the study.

Each eligible subject underwent non-mydriatic fundus photography and MPOD measurement of the study eye using the VISUCAM 500® retinal camera (Carl Zeiss Meditec AG, Germany). A 45º colored retinal photograph centered on the macula was taken and reviewed by a board-certified ophthalmologist for any pathology. After the photograph passed the quality assurance test, the MPOD measurement was performed by a single trained technician. Four MPOD parameters were recorded: (1) maximum optical density (Max OD), meaning the MPOD measured at the peak; (2) mean optical density (mean OD), meaning the mean MPOD within the measurement area; (3) area, meaning the area where macular pigment could be detected; and (4) volume, meaning the sum of all optical densities. MPOD measurements were done thrice, and for each parameter, the average of the 3 measurements was used for data analysis.

Descriptive statistics were used to summarize the data. The Student's *t*-test was utilized to compare continuous variables between two groups, while the chi-square or Fisher exact test was used for categorical data. Pearson's *r* correlation coefficient was used to determine the relationship between duration of device use and MPOD variables. The level of significance was set at 5%. Statistical calculations were performed using Medcalc Statistical Software version 19 (Medical Software Ltd, Ostend, Belgium).

RESULTS

A total of 80 participants, 40 in each group, were included in this study. Table 1 provides the summary of the demographic and clinical profiles along with the VDT exposure details of the study participants. The mean age of the patients in the prolonged VDT exposure group was 27.8 ± 3.7 years, while the mean

age in the low VDT exposure group was 27.2 ± 4.5 years (p = 0.53). Gender distribution was similar in both groups (p = 0.65). There were more participants with errors of refraction in the prolonged VDT exposure group than in the low VDT exposure group (p = 0.02). In addition, the participants in the prolonged VDT exposure group had a more negative mean refraction sphere of –1.73 ± 1.34 D, compared to the mean refraction sphere of the low VDT exposure group of –0.38 ± 0.56 D (p = 0.03). The mean cylinder refraction was similar in both groups. The duration of device exposure in the prolonged exposure group ranged from at least 8 hours to as long as 16 hours for some individuals, with a mean of 10.62 ± 0.34 hours. In contrast, the low exposure group had device exposure ranging from 0 to 6 hours, with a mean of 2.91 ± 0.27 hours, significantly lower than the prolonged exposure group (p <0.0001).

Table 1. Demographic and Clinical Profiles and VDT Exposure of Participants

Profile	Prolonged VDT Exposure (n = 40)	Low VDT Exposure (n = 40)	p-value
Mean age in years ± SD Range	27.8 ± 3.7 20 - 35	27.2 ± 4.5 20 - 35	0.53
Sex, n (%) Male Female	 21 (52.5) 19 (47.5)	 23 (57.5) 17 (42.5)	0.65
With error of refraction, n (%)	15 (37.5)	6 (15.0)	0.02
Mean refraction sphere in diopters ± SD Range	–1.73 ± 1.34 –4.75 to +0.50	–0.38 ± 0.56 –1.25 to +0.50	0.03
Mean refraction cylinder in diopters ± SD Range	–0.78 ± 0.48 –2.00 to -0.25	–1.00 ± 0.35 –1.25 to -0.75	0.53
Mean length of VDT exposure in hours per day ± SD Range	10.62 ± 0.34 8 - 16.50	2.91 ± 0.27 0 - 6	< 0.0001

VDT – video display terminal; SD – standard deviation

Table 2 presents the MPOD parameters of the two groups. The prolonged VDT exposure group had significantly lower mean Max OD of 0.203 ± 0.069 DU compared to that of the low VDT exposure group of 0.247 ± 0.065 DU (p = 0.005). Additionally, the mean value of the mean OD was also significantly lower in the prolonged exposure group at 0.072 ± 0.023 DU compared to that of the low exposure group at 0.086 ± 0.022 DU (p = 0.006). Although the mean area did not show significant difference between the two groups (p = 0.68), the mean volume was significantly less in the prolonged VDT exposure group compared to the low VDT exposure group at 4,755 ± 1,874 DU degrees^2 and 5,902 ± 2,061 DU degrees^2, respectively (p = 0.01).

Table 2. MPOD Parameters Between the Two Groups

MPOD Parameter	Prolonged VDT Exposure (n = 40)	Low VDT Exposure (n = 40)	p-value
Mean volume in DU degrees^2 ± SD Range	4,755 ± 1,874 1,570 - 1,126	5,902 ± 2,061 (2,387 - 11,231)	0.01
Mean area in degrees^2 ± SD Range	65,939 ± 14,208 25,784 - 92,510	67,149 ± 12,212 (45,599 - 92,058)	0.68
Mean of Max OD in DU ± SD Range	0.203 ± 0.069 0.119 - 0.454	0.247 ± 0.065 0.134 - 0.385	0.005
Mean of Mean OD in DU ± SD Range	0.072 ± 0.023 0.05 - 0.16	0.086 ± 0.022 0.05 - 0.12	0.006

VDT – video display terminal; SD – standard deviation; DU – density unit

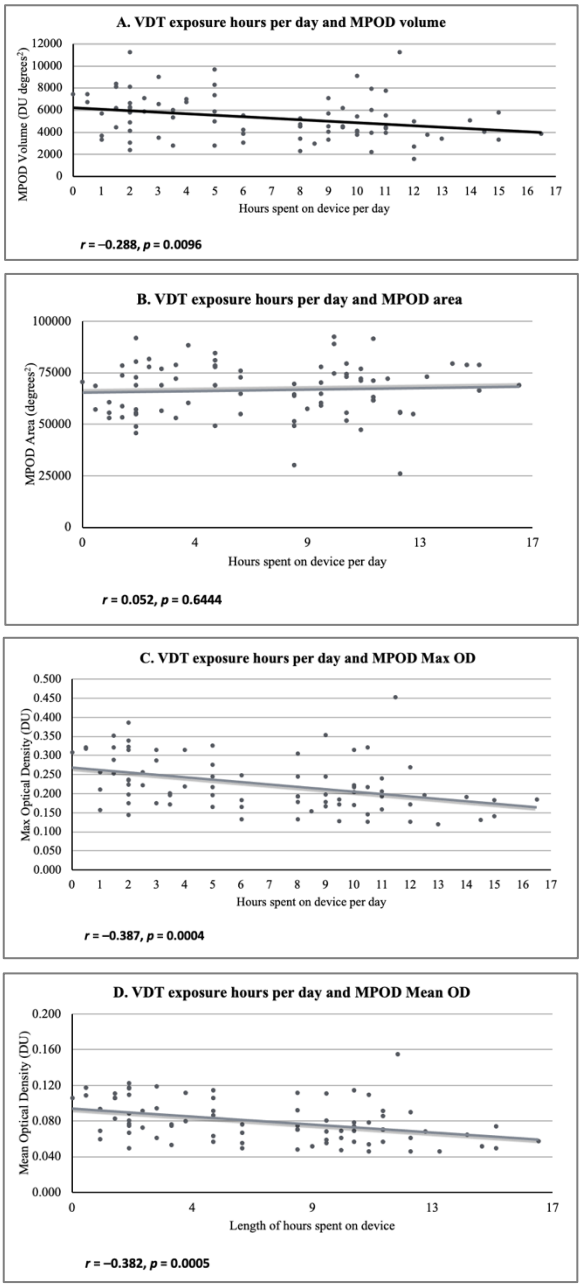
Figure 1 displays scatterplots illustrating the relationship between the length of hours spent on VDTs and various MPOD parameters. Significant inverse associations were observed between device usage and MPOD volume, Max OD, and mean OD, with Pearson's r coefficients of –0.288, –0.387, and –0.382, respectively, and corresponding p-values of 0.0096, 0.0004, and 0.0005. On the other hand, there was no significant correlation between MPOD area and hours spent on devices (r = 0.052, p = 0.64).

DISCUSSION

This study explored the relationship between prolonged VDT exposure and MPOD levels. Participants were divided into two groups: the prolonged exposure group with mean VDT exposure of 10.62 ± 0.34 hours a day, and the low exposure group with mean VDT exposure of 2.91 ± 0.27 hours a day. Our study results revealed that the prolonged exposure group exhibited significantly lower MPOD parameters, including volume, Max OD, and mean OD, compared to the low exposure group. Furthermore, a negative linear correlation was observed between the duration of device use and MPOD volume, Max OD, and mean OD. The

negative Pearson *r* coefficients indicate an inverse relationship, suggesting that the longer the time spent on devices, the lower the MPOD levels. However, these correlations were weak, with Pearson *r* values ranging from –0.288 to –0.387.

Figure 1. Scatterplots of daily VDT exposure hours versus MPOD volume (A), MPOD area (B), Max OD (C) and mean OD (D)



A similar study by Tudosescu *et al.* presented conflicting results regarding the influence of blue light exposure from computer screens on MPOD.[12] Their research found no significant impact of blue light on MPOD levels, even when comparing a group of computer users exposed for a minimum of 8 hours per day, 5 days per week, for 2 years, to a control group. However, several key differences between their study and ours may explain the discrepancy. The study by Tudosescu *et al.* included participants aged 18 to 65 years, unlike our study, which specifically focused on individuals aged 20 to 35. We chose this narrower age range to control for potential confounding factors, such as age-related changes in MPOD and the higher likelihood of systemic diseases in older participants, which could affect the results. Additionally, the time spent using digital devices between the two age groups in their study was not clearly reported. In contrast, in our study, there was a highly significant difference, with the prolonged exposure group averaging 10 hours a day and low exposure group averaging 3 hours a day. Though there is no widely accepted definition of "prolonged exposure" to VDT, prior studies suggested that VDT-related symptoms, such as dry eye, eye strain, and cognitive and sleep disturbances, become more pronounced with increasing hours of device use. Based on these findings, we hypothesized that longer exposure might also lead to a decrease in MPOD, as observed in our results.

The average Max OD in our study was 0.225 DU, which was significantly lower than the findings of a previous Filipino study that measured MPOD across a wider age range of 20 to 70 years, reporting values of 0.39 DU for MPS II and 0.27 DU for the Macuscope machine.[11] We found no established reference database on normal MPOD values when we searched large scholarly databases such as PubMed and Google Scholar. In Tudosescu *et al.*'s categorization of MPOD levels, our subjects would fall into the "very low" range (0 -0.250).[12]

The results of this study showed that 94% of the prolonged VDT exposure group had refractive error, which was significantly more than in the low VDT exposure group. Researches on MPOD, refractive error, and axial length have yielded mixed results. Zheng *et al.*, Czepita *et al.*, and Neelman *et al.* found no correlation,[14–16], while Tong *et al.* reported an inverse correlation between MPOD and axial length in high myopia.[17] Similarly, Benoudis *et al.* found lower MPOD in patients with high myopia and lacquer cracks.[18] Since the prolonged VDT exposure group had a mean spherical refraction of –1.73 ± 1.34 D (mild to moderate myopia), the possibility of myopia influencing the low MPOD

findings in this group cannot be discounted. Screening criteria also contributed to the low mean refraction.

This study has several limitations. First, it did not account for exposure to other light sources, such as sunlight, artificial lighting, or the flash used during fundus photography, nor did it consider the specific time of day when MPOD measurements were taken. These factors could potentially influence individual MPOD levels. However, research by Wenzel *et al.* suggested that MPOD remains stable throughout the day, regardless of typical daily variations in light exposure.[19] Second, the exposure classification relied on self-reported screen time, which is susceptible to recall bias and inaccuracies. Additionally, this study did not specify the type of VDT used. Different screens emit varying levels of blue light, which may differentially affect macular health. Other screen settings, such as brightness and contrast, may also play a role, but were not examined in this study. Furthermore, gender differences in MPOD were not analyzed. Previous studies have indicated that female participants often exhibit lower MPOD levels compared to males.[20] Finally, the study's inclusion criteria limited participants to those with mild to moderate refractive errors, which prevented us from assessing the potential impact of high refractive errors, such as high myopia, on MPOD levels.

This study found a weak but significant negative correlation between prolonged VDT exposure and MPOD levels, suggesting that extended screen time may contribute to reduced MPOD. While the correlation was modest ($r = -0.387$ for Max OD), the findings highlight potential risks to macular health with excessive VDT use. Given the role of macular pigments in visual function and eye protection, these results underscore the importance of preventive strategies, such as limiting screen time, optimizing dietary intake of lutein and zeaxanthin, and incorporating protective measures like blue light filters. However, due to the study's cross-sectional design and potential confounding factors, causation cannot be established. Future longitudinal and multi-center studies with larger sample sizes, objective screen time tracking, and dietary assessments are needed to further investigate the long-term impact of VDT exposure on macular health.

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