The influence of multi-way sources of illumination of monitor screens and changes in the color temperature on the excretion of melatonin metabolite

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Abstract. Intensive use of computers leads to an increase in the light load on the human body. The purpose of this research was to study the impact of the differential illumination of matrices of computer monitors (CM) on a melatonin-forming function, in which healthy male volunteers (average age 22.8 ± 2.09 years) took part. The light exposure was carried out by series for seven days with the help of CM, from which volunteers in the evening (from 9 pm to 11 pm) read standard text. CM had various backlit devices: Cold Cathode Fluorescent Lamp (CCFL) and White Light Emitting Diode (WLED), different color temperatures (CT). After each series, the excretion of 6-sulfatoxymelatonin (6-SOM) with urine was investigated. The peak intensity (PI) and the dominant wavelength (DW) in the WLED series, the parameters turned out to be within High Energy Visible Light (HEVL). The study revealed reliable differences in 6-SOM concentrations in different series of studies with indicators in the series with wised and CT 5512-5903 K. The research also detected correlations between the indicators 6-SOM, the values of PI (R = 0.692, p = 0.05) and the DW (R = 0.587, p = 0.01), which are in the HEVL range.

1. Introduction

Today, light emitting diode (LED) - technologies are widely used as a source of artificial lighting in order to save energy in the premises of industrial, domestic purposes and in educational institutions. LEDs are also used for the highlighting of computer monitor matrices (CM) in personal, tablet computers, laptops, smartphones and TVs. The almost uncontrolled use of CM by young people, especially in the conditions of digitalization of the education system, is of particular concern. The identified "blue light" phenomenon of LEDs within the so-called High Energy Visible Light (HEVL), as well as a small awareness of the population about the possible potential danger of spectral composition of radiation of health LEDs, makes this problem beyond the concept of voluntary risk.

Recently, a term, reflecting the essence of the problem, appeared: light pollute. LED lighting can have an adverse effect on a psycho-emotional state, cause headaches, cause tension of the organ of vision, up to retinal damage and loss of vision, as well as in some cases, potentiates skin diseases, changing circadian human rhythms [1, 2]. Given the importance of the issue of the light load by the American National Toxicological Program, a group of experts at an open seminar called "Shift work at night. Artificial lighting at night and violation of daily rhythm ", during which the issues of impact of artificial lighting were discussed, as well as the conclusions about the prospects for research on the role of the light load in violation of circadian rhythms in humans were done [4].
In the process of light perception, melanopsin is directly involved in the retina cells. A number of authors indicate the need for a detailed study of the functions of melanopsin in the assessment of the brightness of light, including from the self-losing objects (screens of tablets, computers, smartphones), and suppressing melatonin hormone products with a circadian phase change [4, 5], develops arguments in favor of adoption circadian stimulus for quantitative estimation of light in the premises [6]. Melatonin (N-acetyl-5-methoxytryptamine) is a neuroendocrine hormone, synthesized predominantly by pineal corpus depending on the intensity of light. The continuous impact of light, as in the case of pinealactomy, completely eliminates the natural circadian rhythms of melatonin leading to maintenance of its blood concentrations at low day values [7]. The light effect of LED - sources causes typical non-physical reactions to light and can suppress melatonin synthesis [8].

Morphological changes in the epiphysis under the influence of electromagnetic radiation from communication devices have been experimentally shown [9]. CM, which are self-luminous electronic devices with LED backlight produce, including short-wave radiation, close to the peak of the sensitivity of the melatonin suppression [10]. In this regard, the goal is as follows: the study of the impact of the illumination of a different type of matrices CM on melatonin products.

2. Material and methods
The study was carried out on 6 male volunteers aged 22.8 ± 2.09 years from 21 to 26 years. The surveyed did not have any clinically significant pathology, the testees were in the standard wake-up mode, sleep and illumination, a typical diet, excluding coffee, alcohol, pharmacological drugs, cigarettes smoking. The light exposure was carried out by series with screens CM from which within 2 hours in the evening (from 9 pm to 11 pm) volunteers read standard text. The screens had different highlighting devices Cold Cathode Fluorescent Lamp (CCFL) and White Light Emitting DIODE (WLED) and different color temperatures (CT). The experiment was conducted in four series: in the 1st and 2nd series wised monitors with a CT were used, located within 3545-3998 K and 5512-5903 to, respectively. In the 3rd and 4th series, there were CCFL monitors with CT 3501-3612 K and 5609-5870 K. Measurements of spectral and temperature characteristics of monitors were performed by a BTS-256 spectrophotometer with an adapter having a scattering glass in light measurement mode.

Each series lasted seven days, between the series there was the same break - seven days. The melanomine-forming function of the pineal gland was investigated by determining the nightly excretion of melatonin metabolite (6-sulfoymelatonin (6 - SOM)) in the urine. Of the total volumes of night urine, collected in the morning on the first day after each series of light exposure, samples (5 ml) were selected, which were stored at a temperature of -20°C no more than 3 months. The concentration of 6-SOM in samples was determined by an immunoassayment method on an analyzer ELISA - OEP (Russia) using standard sets of IBL - Hamburg (Germany) and constructing a calibration graph of the dependence of the optical densities of standards from the concentration of the relevant standards.

Statistical analysis of data was carried out using non-parametric statistics (median, percentedge (P25 / P75); Mann-Whitney criterion, a Spearman coefficient) using the Statistica 8.0 program.

3. Results
The definition of light and color parameters of screens used in different series are shown in Table 1.
Table 1. Results of measuring color temperature, illumination and spectral distribution of light screens display information (Me; P25 / P75).

| Parameters          | Series 1          | Series 2          | Series 3          | Series 4          |
|---------------------|-------------------|-------------------|-------------------|-------------------|
| CT (K)              | 3678; 3547/3992   | 5522/5898         | 3507/3626         | 5631/5849         |
| Illuminance (lx)    | 140.86; 132.51/147.06 | 146.36; 139.25/152.72 | 138.56; 131.42/145.33 | 142.29; 134.43/149.90 |
| Peak wavelength (nm)| 620.72; 597.30/632.90 | 453.60; 449.03/461.11 | 544.22; 535.47/554.48 | 519.02; 510.44/523.04 |
| Center wavelength (nm)| 623.33; 619.38/630.45 | 454.89; 448.27/459.39 | 544.20; 536.84/551.98 | 521.86; 516.02/526.66 |
| Dominant wavelength (nm)| 579.42; 568.08; 567.01/593.74 | 452.20; 448.08/457.24 | 560.33/574.21 | 518.55/527.86 |

Increasing the color temperature of monitor screens with backlit matrices as a WLED and CCFL with an unreliable difference in the illumination values (p>0.05) gives a different pattern of spectral distribution.

Peak intensity and the dominant wavelength in all series, except for the 2nd, were within 510 - 633 nm. In the 2nd series, the parameters were within the so-called HEVL (High Energy Visible Light), high-energy light (Figure 1).

Figure 1. Spectral radiation of the monitor screen with a wised backlight of the matrix during color temperature 5899.7K (Series 2).

The radiation of monitor screens having the CCFL backlight has a characteristic spectral distribution shown in Figure 2.
Figure 2. Spectral radiation of the monitor screen with CCFL backlit matrix during color temperature 5676.7K (Series 4).

In the first series, peak intensity and the dominant wavelength were in the range of 567 - 632 nm. However, with a more detailed consideration of the spectral radiation, we also see the presence of a low peak of high-energy blue light in the HEVL range (Figure 3).

Figure 3. Spectral radiation of the monitor screen with a wised backlight of the matrix at color 3571 K.

Thus, even with the "prosperous" total indicators of the spectral distribution, a blue peak of less energy is observed, but located within the HEVL (445-455 nm).

The study of excretion 6 - SOM (Table 2) revealed reliable differences (U-test) in the concentrations of metabolite melatonin between the series.

Table 2. Concentration of 6-som (in ng / ml) in the urine (me; p25 / p75).

| Series | Median   | p25/p75   | P (Mann–Whitney U-test) |
|--------|----------|-----------|-------------------------|
|        |          |           | 1 | 2   | 3   | 4   |
| 1      | 146.09   | 143.56/148.71 | - | >0.05 | <0.01 | <0.05 |
| 2      | 120.23   | 117.04/123.90 | >0.05 | - | <0.01 | <0.05 |
| 3      | 180.18   | 172.42/184.08 | <0.01 | <0.01 | - | >0.05 |
| 4      | 154.94   | 152.65/160.31 | <0.05 | <0.05 | >0.05 | - |
The smallest rates of excretion of 6-SOM are detected in the second series, which may indicate a decrease in the production of hormone melatonin.

The correlation analysis between the studied parameters of the monitor screens and the concentration of metabolite melatonin over the series revealed the presence of reliable correlations in the 2nd series with the peak intensity values (Ro = 0.688; p = 0.01) and the dominant wavelength (Ro = 0.532; P = 0.05) The HEVL range allows assuming their suppressing effect on the melatonin-forming function of pineal gland.

Increasing the color temperature of monitor screens with different backlit matrices with an inaccurate difference in the illumination values (p> 0.05) gives a different pattern of spectral distribution. In this case, the peak intensity and the dominant wavelength in a series with highlighted wised and CT 5512-5903 K, turned out to be within the so-called HEVL - high-energy light.

The identified reliable correlations between the results of the study of the excretion of melatonin metabolite and the parameters of the CM make it possible to assume their suppressing effect on the melatonin-forming function of pineal gland. The results obtained are consistent with the research on the use of displays at night [11]. This factor was associated with the delay in sleep offensive, reduce the duration of sleep and the suppression of the production of melatonin, proven by a little efficiency in the regulation of melatonin products of the Night Shift application, aimed at changing the spectral composition of the self-losing displays on portable Apple electronic devices.

The study of the influence of the CT lighting (1600 K-14000 K, 200 lx) during the daytime was done, visual performance has shown the absence of changes in visual acuity, contrast sensitivity and the appearance of drowsiness [12]. However, in the same study, a violation of color discrimination was revealed when illuminated by polychromatic white light <2000 K, and the growth of CT potentiated the suppression of melatonin production.

4. Conclusions
1. The increase in the CT screens of the CM with backlit matrices as a wised and CCFL with an unreliable difference in the illumination values (p>0.05) gives a different pattern of spectral distribution. An increase in the color temperature of the WLED monitors with backlit monitors leads to a significant (p <0.05) reduction in excretion of 6-som.
2. The identified correlation bonds between the concentration of melatonin metabolite with the peak intensity values (Ro = 0.688, at the level of significance p = 0.01) and the dominant wavelength (Ro = 0.532, at the significance level p = 0.05), which are in the HEVL range suggest their inhibitory effect on the melatonin-forming feature of the pineal gland.

5. References
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