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Review Article

The Study of Impact of Incandescent and White Color LED Electric Lamps on the Functional Condition of Ocular Surface and Autonomic Regulatory Mechanisms

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Abstract

The results of our research and data from literary sources allow us to conclude that the spectrum of room lighting with incandescent and LED electric lamps is significantly different from each other and, therefore, their effects on the eye and the balance of the autonomic nervous system are different. In particular, a study using a spectrometer showed that the illumination of an incandescent electric lamp covers the full range of the visible spectrum, while a sharp failure of the spectrum of white color light was observed in 470 when illuminating a Phillips LED 620 lamp. 500 nm range.

The dynamics of the diameter of the pupil of the eye was different under the conditions of illumination with incandescent and white LED electric lamps. In particular, when illuminated by a white LED electric lamp, the diameter of the pupil of the eye was greater than when illuminated by an incandescent electric lamp. Studying the functional condition of the ocular surface through the OSDI study revealed an acute category of eye symptoms in 30 out of 100 cases. This fact made it necessary to include this contingent to evaluate the autonomic nervous balance. The study of heart rate variability found a statistically reliable increase in heart rate, as well as a significant increase in the stress test indicator under the conditions of the LED electric lamp, as opposed to the incandescent electric one. The latter gives us a reason to conclude that the white LED electric lamp significantly worsens the functional condition of the organ of vision and disturbs the balance of the regulatory mechanisms of the autonomic nervous system. The results of their own studies have shown that the lighting of classrooms can cause completely unpredictable negative consequences in children [5], because failure in the blue color range of the spectrum can cause photochemical damage to the retina [6,7]. Also, one-hour irradiation with LED electric lamps in sleeping children causes a significant release of cortisol in the blood, which is much higher than the normal value [8]. At the same time, it is important to note that melanopsin is most sensitive in the 460-480 nm range of the light spectrum. In this range, LED lamps have a pronounced cutoff (480 nm), which determines inadequate pupil control and possible retinal damage.

Keywords: LED Lamps; iPADs; Ocular Surface Disease Index (OSDI)

Introduction

Total of 80-90% of humans get information be means of the vision. The vision is the transformation of electromagnetic irradiation energy of visible range induced by retinal photoreceptors stimulation and the transfer of information to the corresponding brain areas. The eye functions under various conditions of lighting (during the day, at twilight and at night). The light induces a secretion of a number of hormones (melatonin and cortisol), as well as the changes in circadian rhythms.

The strong development of scientific-technical progress leads to the creation of artificial lighting systems. Among them an incandescent and light emitting-diodes have a special importance. In the last years a widespread use of low energy consumption small sizes LED electric lamps in household, in mobile and smartphones screens, as well as in planshets, iPADs, electronic books, in liquid crystal displays, etc. the study of the impact of white LED and incandescent electric lamps lighting on the vision organ has been put on the agenda. As known, white color light-emitting diodes spectrum significantly differs from the spectrum of traditional incandescent electric lamp.

Materials and Methods

The study of the lighting spectrum of incandescent and LED electric lamps impact on functional condition of ocular surface and the balance of autonomic nervous system has been considered as an interesting and important research issue.

By means of ocular surface disease index (OSDI) the relation of ocular symptoms to vision function has been established. Visual acuity was measured using Visometer (BCNA). Ocularly healthy persons were chosen. Sclera of all the healthy persons was unchanged - in the norm, eye cornea was spherical and transparent, color shell – structural, crystal – transparent, vitreous body – in the norm.

By the use of OSDI survey the ocular symptoms during normal, moderate and severe forms have been assessed (Table 1).

The study of vegetative regulatory mechanisms was carried out using the method of heart rate variability by means of ECG digital electroencephalography according to the attached program in a resting state at 10-11 am and 1.5-2 hours after the breakfast. The research was carried out in conditions of comfortable temperature, humidity, atmospheric pressure, when the invasion of atmospheric front was not observed. By means of survey method the life-style of the studied object (food, alcohol and tobacco consumption, physical and emotional tension) [1]. The standard software of heart rate variability has allowed the getting the following statistical indicators: R-R interval, H-R – average arithmetic, SDNN – a standard deviation, SI – stress-index), where Mo is a mode, ΔMo – a mode amplitude.

SDI Scores	OSDI Category
0-12	Normal
12-22	Mild
23-32	Moderate
33-100	Severe

Table 1: The assessment of ocular symptoms by OSDI survey.

Three frequency ranges VLF, LF, and HF were distinguished by the spectral analysis. By means of spectral analysis three frequency ranges were identified: a spectrum of lighting with incandescent and LED electric lamp was measured using a spectrometer (https://www.stellarnet) [1], while a brightness – by digital lux meter (the Firm – BENETECH Digital Lux Meter SM1010).

Before involving in the research the participants were informed that the study was voluntary and the survey - confidential, ant that they could stop their participation at any time. Also a written consent of the participants with personal signature was necessary. The above-said is in accordance with the Helsinki Ethics Principles [2].

The results obtained were statistically processed using both parametric and nonparametric methods [3].

Results and their Discussion

By means of the experiments carried out using a spectrometer it has been established that a lighting with an incandescent electric lamp covers a full range of the visible light (Figure 1), while in warm white color light spectrum of Philips LED 620 electric lamp, a sharp failure was observed in 470-500 nm range (Figure 2).

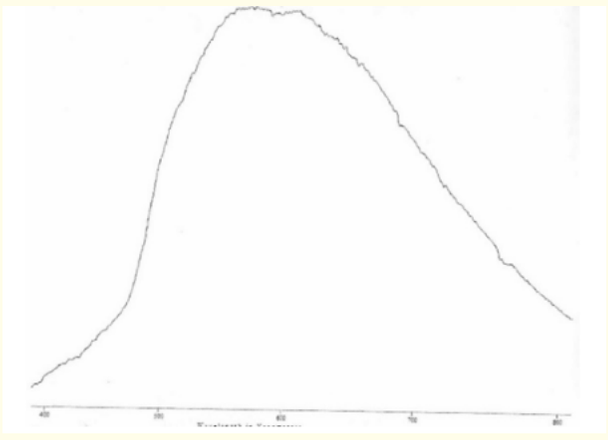

Figure 1: The spectrum of an incandescent electric bulb.

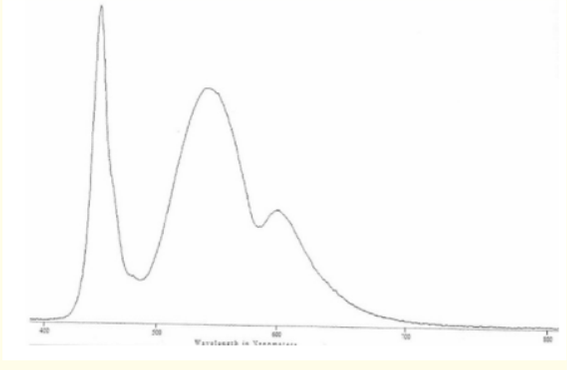

Figure 2: Warm white color spectrum of Philips LED 620 nm.

The impact of a white color LED electric lamp on the reflex of pupil of the eye has been studied. To this end, we photographed the pupil of the eye with room bright sun under the conditions of a lighting with an incandescent and white color LED electric lamps.

Total of 5 series of the experiments have been carried out. Before the research a degree of lighting was measured using the lux meter: 1) it was equal to $65x10^{10}$ lux at the open window in the sun; 2) it was $58x10^{10}$ lux 1.5 m from the window in the "depth of the room"; 3) at a distance of 3.5 m it was equal to $45x10^{10}$ lux; 4) in case of a white LED electric lamp lighting it equals to $400x10^{10}$ lux and the light source was at a distance of 20 cm from the object; 5) under the lighting with an incandescent electric lamp the lighting was $300x10^{3}$ lux and a distance from the object was 35 cm.

As a result of the research it has been established that under conditions of a natural lighting near the window a diameter of the pupil of the eye was 6.4 ± 0.24 conditional unit (c.u.), while at a distance of 3.5 m from the window in the depth of the room it increased up to 9.0 ± 0.37 c.u. As to a lighting with a white color LED electric lamp, a diameter of the pupil of the eye of studied person was 6.2 ± 2.0 c.u., while under the conditions of lighting with incandescent electric bulb it made up 5.9 ± 3.0 c.u.

Each proband was in a semi-recumbent position at a lighting with a room incandescent and a white color electric lamps on an empty stomach; in the morning the duration of each lighting made up 20 minutes.

An acute category of ocular symptoms studied by OSDI was revealed in 30 probands out of 100, in which the balance of autonomic nervous system was studied using a heart rate variability method under the conditions of lighting with an incandescent and LED electric lamps (Tables 2 and 3).

HR			SDNN			SI		
1	2	3	1	2	3	1	2	3
Incandescent electric lamp	**White LED electric lamp**	**Incandescent electric lamp**	**Incandescent electric lamp**	**White LED electric lamp**	**Incandescent electric lapm**	**Incandescent electric lamp**	**White LED electric lamp**	**Incandescent electric lamp**
72,7 ± 1,4	74,2 ± 1,5	72,1 ± 1,1	73,5 ± 4,2	65,9 ± 3,9	74,3 ± 4,2	172,9 ± 17	277,5 ± 32	185,4 ± 19
	1-2 t = 1,93 P = 0,6	1-3 t = 2,9 P = 0,37		1-2 t = 2,5 P = 0,02	1-3 t = 0,3 P = 0,8		1-2 t = 4,7 P = 0,0001	1-3 t = 0,93 P = 0,36
		2-3 t = 2,96 P = 0,006			2-3 t = 2,5 P = 0,02			2-3 t = 4,2 P = 0,0001

Table 2: Dynamics of statistical characteristics of heart rate under conditions of the lighting with an incandescent and a white LED electric lamps during 20 min. irradiation.

VLF%			LF%			HF%		
1	2	3	1	2	3	1	2	3
Incandescent electric bulb	White LED electric bulb	Incandescent electric bulb	Incandescent electric bulb	White LED electric bulb	Incandescent electric bulb	Incandescent electric bulb	White LED electric bulb	Incandescent electric bulb
30,8 ± 0,9	30,3 ± 1,2	31,2 ± 1,0	37,0 ± 0,7	36,9 ± 0,84	35,8 ± 0,6	31,5 ± 1,4	34,0 ± 1,3	33,0 ± 1,1
	1-2 t = 0,5 P = 0,6	1-3 t = 0,42 P = 0,7		1-2 t = 0,1 P = 0,9	1-3 t = 1,9 P = 0,07		1-2 t = 1,9 P = 0,06	1-3 t = 1,0 P = 0,3
		2-3 t = 0,9 P = 0,37			2-3 t = 1,4 P = 0,018			2-3 t = 1,0 P = 0,03

LF/HF %		
1	2	3
Incandescent electric bulb	White LED electric bulb	Incandescent electric bulb
1,2 ± 0,05	1,2 ± 0,06	1,14 ± 0,05
	1-2 t = 0,9 P = 0,35	1-3 t = 1,4 P = 0,16
		2-3 t = 0,46 P = 0,65

Table 3: Dynamics of spectral characteristics of heart rate under conditions of the lighting with an incandescent and a white LED electric lamps during 20 minutes irradiation.

After 20 minutes of irradiation with an incandescent electric lamp, a heart rate made up 72.7 ± 1.4; after 20 minutes of irradiation with a LED electric lamp it increased up to 74.2 ± 1.5, however, a statistical difference between them was not reliable, and a repeated irradiation with an incandescent electric lamp revealed a statistically reliable increase in the frequency of heart rate, as compared to the irradiation with LED electric lamp.

Based on this experiment, we can conclude that an irradiation with LED electric lamp reliably increases a pulse frequency, but within the limits of norm. Significant changes were also experienced in the standard deviation (SDNN), which at lighting with LED electric lamp, as compared to background index at a lighting with an incandescent one, reduced. But during 20 minutes lighting with an incandescent electric lamp it returned to its initial index again.

The indicator of stress-index (SI) is of great interest, a level of which significantly increased.

The background and control indicators of room lighting with an incandescent electric lamp were compared to those during lighting with a white color LED electric lamp. As to the dynamics of spectral characteristics of heart rate, under the conditions of lighting with an incandescent and a white color LED electric lamps, a statistical reliability has not been revealed (Table 3).

The dynamics of a diameter of the pupil of eye under the conditions of lighting with an incandescent and a white color LED electric lamps was different. In particular, at lighting with a white color LED electric lamp a diameter of the pupil of eye exceeded that of lighting with an incandescent electric bulb. The study of

a functional condition of ocular surface by means of OSDI survey has revealed an acute category of ocular symptoms in 30 probands out of 100. This fact led to the necessity of the involvement of this contingent for the assessment of the balance of autonomic nervous regulation. The study of heart rate variability has established a statistically reliable increase in heart rate frequency, as well as a significant increase in stress-test indicator under the conditions of LED electric lamp, unlike an incandescent electric one. The latter gives us a reason to conclude that a white color LED electric lamp significantly worsens a functional condition of vision organ and disturbs the balance of regulatory mechanisms of autonomic nervous system.

Conclusion

Based on the results of our clinical research and also based on literary sources, the lighting of classrooms can cause absolutely unpredictable negative consequences in children [5], because failure in the blue color range of the spectrum can cause photochemical damage to the retina [6,7]. Also, one-hour irradiation with LED electric lamps in sleeping children causes a significant release of cortisol in the blood, which is much higher than the normal level [8]. At the same time, it is important to note that melanopsin is most sensitive in the 460-480 nm range of the light spectrum. In this range, light-emitting diode lamps have a pronounced cut (480 nm), which determines the inadequate control of the pupil and possible damage to the retina [9].

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