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THE RELATIONSHIP BETWEEN CILIARY MUSCLE FATIGUE AND THE TYPE OF ARTIFICIAL LIGHT USED TO ILLUMINATE THE AREA OF VISUAL WORK

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Abstract. The relationship between the degree of eye fatigue resulting from visual work and type of light source used to illuminate the field of work was assessed. The tests were performed using artificial light sources: fluorescent lamps, incadescent lamps, high pressure mercury (vapour) and high pressure sodium (vapour) lamps. The assessment was performed on two groups of 10 women each, of which one included women without, and the other with, refraction errors. On the basis of changes of nearer vision point and dispersing lens tolerance, it was found that sodium light produced the highest visual fatigue in the test women, especially in those with refraction errors.

INTRODUCTION

Visual work leads to fatigue of the organ of vision. The magnitude of the fatigue can depend on external factors, the major being light and work difficulty, and on internal factors, the major including errors of refraction and accommodation and convergence disturbances (3, 13).

The relationship between eye fatigue and the level of illumination luminance distribution in the work field and the degree of contrast between the workpiece and the background have been already studied in some detail. It was found that the type of artificial light source can affect: the magnitude of the subjective symptoms of visual fatigue (2, 5, 8, 11) the degree of glare at equal luminance (5), the efficiency and precision of visual work (6, 9, 10, 11) the level of general fatigue and the degree of variation of some physiological fatigue symptoms during work (9, 10).

The question whether the magnitude of eye fatigue resulting from visual work depends on the type of artificial light source used to illuminate the surface of the visual work, when the remaining parameters of the light field are the same, has not yet been unequivocally solved. It was therefore, decided to evaluate, in this respect,

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artificial light sources, such as incadescent and fluorescent lamps, high pressure mercury (vapour) and high pressure sodium (vapour) lamps. The light emitted by those sources differs widely in its spectral content and pulsation, the latter being small for the luminous flux of the incadescent lamps and high for that of the discharge-type lamps. The condition of the fatigue can be evaluated by measuring the deterioration of contraction and relaxation of the muscles participating in the performed work. During visual work at near distance requiring accommodation, the ciliary muscle is most active and the measurement of its contraction and relaxation ability is often used to evaluate eye fatigue resulting from visual work (1, 3, 4, 7, 12). The fatigue depends on workload, and the workload is a resultant of work requirements and of individual's capacities. Refraction errors constitute one of the factors which reduce the individual's capacities and increase the workload.

Therefore, the fatigue resulting from visual work, performed under conditions of light from various types of lamps was evaluated in groups of persons without errors of refraction, and with astigmatism.

MATERIALS AND METHODS

Characteristics of the test groups:

The study was carried out in two groups of women who on the basis of medical examinations were considered to be healthy.

Group I – 10 women aged 31.6±4.4. years without refraction errors and without any other deviations from the normal state of their visual systems.

Group II – 10 women aged 31.4±3.6 years with single- or double-side 1.0 to 1.5 D astigmatism, except of one who had 2.0D astigmatism at one eye and emmetropy at the other. The women worked without any glass correction.

Characteristics of the visual work:

The test women performed proof-reading work, which involved finding and marking specified symbols in three alternate graphic paper tests. The dimensions of the symbols were 10 mm, and the dimensions of their details, depending on the test type, were 1, 2, or 5 mm.

Characteristics of light conditions:

The tests were performed in a specially adapted room provided with artificial light only.

The following were used as light sources supplied from a single-phase electric current:

F – 40 W LDC fluorescent lamps, 6000 K
I – 200 W incadescent lamps, 2850 K
M – 400 W LRF high pressure mercury (vapour) lamp, 4700 K
S – 400 W WLS high pressure sodium (vapour) lamp, 2100 K.

Luminous flux pulsation coefficient: F – 0.85, I – 0.15, M – 0.85, S – 0.95. Ilumination at the area of the visual work was always 500 lx and, regardless of the light source used, the uniformity ratio of the illumination and luminance distribution in the area of the visual work were the same.

PROCEDURE

The tests were performed between 8.00 a.m. and 13.00 p.m. Each woman performed the same visual work four times for 4 hours (wiht 10-minute break after 2 hours) under randomly selected light conditions (F, I, M and S). The time interval between two consecutive tests on each woman was 2 to 7 days.

Nearer vision point (NVP) and dispersing lens tolerance (DLT) were assessed before and after work.

NVP was assessed by measuring the smallest distances at which a test text equivalent to the D-0.5 Snellen Table text was still readable when viewed with both eyes.

DLT was measured individually for each eye by placing dispersing lenses of increasing strength in front of the eye and determining the strength, in doptries, of the lens at which the tested person had still full distance visual acuity when reading digital optotype tables from 5m distance.

RESULTS

Mean NVP (cm) and DLT (D) values before and after work, and the mean differences between them are given in Table 1. The statistical significance of the results, before and after work, was evaluated by the difference test, and that between the results for different light – by means of the t-Student test.

In Group I, NVP distance was significantly greater after work under conditions of each of the tested light sources, however signifcant differences in the values of NVP distance decrease attributable to the type of light source, were detected. DLT remained unchanged after work under conditions of F, I and M lights, while for S light. DLT deterioration was statistically significantly worse than for F and I lights.

In Group II, NVP was significantly more distant after work under conditions of each of the tested light sources; for S light, the increase of the NVP distance was significantly greater than for F and I light. DLT remained unchanged after work under conditions of light from source I, while DLT deterioration was significantly greater for F. M and S light. DLT deterioration after work under conditions of M and S lights was in this group significantly greater than after work under conditions of I light.

DISCUSSION

Fatigue of the ciliary muscle, just like fatigue of any other muscle, results in deterioration of its contracting ability and is manifested by increasing the distance of the nearer vision point (NVP). With greater fatigue, also the relaxation of the muscle may become incomplete, which is manifested by impaired dispersing lens tolerance (DLT). In an attempt to evaluate the relationship between the fatigue and the artificial light source type, it can be stated that in group I (women without refraction errors) sources F and I caused least loading. Although the work performed at F and I light caused statistically significant increase of NVP distance, DLT was unchanged. M light seems to cause somewhat greater load, as the statistically significant

Tablel 1. Changes of nearer vision point (NVP) and dispersing lens tolerance (DLT) before and after work under light from different lamp types (mean values ± SD) and the after work − before work difference (mean difference ± SD) in the group of persons without refraction errors − I and with astigmatism − II.

Test group	Tested visual function	Light source used to illuminate the area of work											
		fluorescent lamps			filament lamps			mercury-vapour tubes			sodium-vapour tubes		
		before work	after work	difference	before work	after work	difference	before work	after work	difference	before work	after work	difference
I.	NVP (am)	11.3 ±1.8	12.2 ±2.1	0.9* ±0.6	11.9 ±1.1	13.0 ±2.1	1.1* ±1.0	11.2 ±1.7	12.4 ±2.2	1.2* ±0.8	11.3 ±1.5	12.4 ±1.9	1.1* ±0.5
	DLT (D)	4.63 ±1.9	4.72 ±2.1	0.09 ±0.54	3.78 ±1.6	3.86 ±1.7	0.03 ±0.86	4.8 ±2.1	4.7 ±2.0	0.10 ±0.75	4.92 ±1.0	4.65 ±1.8	0.26* ±0.4
II.	NVP	10.5 ±1.2	11.3 ±1.6	0.95* ±0.4	10.6 ±1.0	11.5 ±1.0	0.9* ±0.4	10.6 ±1.1	11.7 ±1.4	1.1* ±0.4	10.6 ±1.2	12.0 ±1.6	1.4** ±0.9
	DLT (D)	4.87 ±2.3	4.7 ±2.3	0.17* ±0.5	4.97 ±2.1	5.02 ±2.1	0.05 ±0.68	4.70 ±2.3	4.45 ±2.3	0.25* ±0.5	4.92 ±2.1	4.53 ±2.2	0.35* ±0.3

* after work − before work-difference, statistically significant $p < 0.05$;
** $p < 0.01$.

deterioration of NVP was accompanied by a slight (statistically insignificant) deterioration of DLT. S light proved to cause the greatest load, as both NVP and DLT were significantly impaired. The deterioration of DLT under S light was significantly greater than DLT changes under F and I lights.

In Group II (women with astigmatism) the relationship between the degree of the ciliary muscle fatigue and the type of artificial light was much more evident than in Group I. The smallest ciliary muscle fatigue was found after work under conditions of light from source I – statistically significant increase of NVP with unchanged DLT. Somewhat greater fatigue of the ciliary muscle was found after work under F light – statistically significant deterioration of NVP and DLT, although the differences between I and F lights proved to be statistically insignificant. Under M light DLT deterioration was significantly greater than under I light. S light proved to cause most fatigue in the group; increasing NVP distance and DLT deterioration was significantly greater than under F and I lights. Thus, for both people without, and still more for people with, refraction errors, visual work under sodium light proved to cause most fatigue.

In some other studies evaluating the dynamics of visual functions under the light from incadescent lamp and high pressure sodium (vapour) lamp it was found that NVP distance was greater for the sodium lamp than for the incadescent lamp (1).

The assessment of the effects of the incadescent lamp and sodium vapour lamp vs. age revealed that the adverse effect of the sodium light increased with age, when compared with the light of incadescent lamp (14).

The results of our study confirm the adverse effect of the sodium light on the efficiency of the organ of vision reported by other authors (1, 14, 15) and indicate that sodium light should not be used for visual work which requires precision.

It seems that the adverse effect of sodium light may be attributed to the spectral composition of the light.

The accommodation response is supposed to be stimulated by chromatic aberration, therefore accommodation in almost monochromatic sodium light may prove to be more difficult than in the wider-spectrum light from other sources.

Light pulsation does not seem to result in evidently greater fatigue in persons without refraction errors. All studied light sources were supplied from a single-phase electric current mains, therefore light pulsation was not suppressed; nevertheless accommodation fatigue in the pulsating light from the lamps F and M was not found to be significantly greater than that in the practically non-pulsating light from the incadescent lamps. This is confirmed by the results of other studies, in which suppressing the pulsation of the sodium-lamp light by connecting the lamp to three-phase electric current supply mains did not prevent increased NVP distance in the sodium light as compared with the light from the incadescent lamp (1,14).

In the group of astigmatic women, on the other hand, luminous flux pulsation seemed to increase the fatigue. The fatigue of the ciliary muscle following visual work performed in light I was lower than in the light from all studied discharge-type light sources. Evidently higher accommodation fatigue in the sodium than in the light F in this group could be attributed to a combined effect of spectral composition and luminous flux pulsation of the sodium lamp.

To sum up, it can be stated that for visual work, sodium light is the one which causes the highest eye fatigue, probably due to its spectrial composition. Luminous

flux pulsation does not significantly affect fatigue in persons without refraction errors, it does, however, evidently affect visual work (work discomfort) in persons with astigmatism.

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