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MEDICAL, PSYCHOLOGICAL AND HYGIENIC SIGNIFICANCE OF ARTIFICIAL LIGHTING IN HOSPITAL ROOMS

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Abstract: Patients and medical staff in modern hospitals, particularly in operating, resuscitation and intensive care units, spend much of the day and night under artificial lighting. The quality of this lighting may influence circadian regulation, psychological state, recovery and visual performance.

To assess the sanitary-hygienic, physiological and psychological effects of artificial lighting parameters (illuminance, correlated color temperature, color rendering index and flicker) in hospital rooms on patient recovery and on the performance of medical staff.

Keywords: artificial lighting; illuminance standards; LED technology; human-centric lighting; circadian rhythm; melatonin; hospital hygiene; asthenopia; resuscitation; correlated color temperature (CCT).

INTRODUCTION

Relevance of the problem

Healthcare facilities are specialized architectural and engineering environments designed for restoring health, performing complex surgical interventions and providing uninterrupted care to critically ill patients. The effectiveness of a hospital depends not only on high-technology equipment and the qualifications of its specialists but also on the indoor environment: microclimate, air quality, noise and lighting. Physical and chemical environmental factors are recognized determinants of health across biological systems and populations [1, 2], and their hygienic assessment against normative requirements is an established approach in preventive medicine and occupational health [3, 5, 6].

Within the hospital environment, artificial lighting is more than a technical means of enabling vision. It is a neuroendocrine factor that regulates biological and physiological processes of the human body. In modern hospitals, especially in resuscitation, intensive care and operating units, natural daylight is limited or absent, so patients and staff are exposed to artificial light sources around the clock. Inappropriately selected light sources, illuminance that is too low or too high, flicker and an unsuitable spectral composition may disturb circadian rhythms, suppress the synthesis of melatonin and may contribute to impaired immune function.

Circadian rhythms and the photobiology of the eye

In the early 2000s, a third class of photoreceptors was discovered in the retina: the intrinsically photosensitive retinal ganglion cells (ipRGCs). These cells do not take part in forming the visual image. Instead, they detect the intensity and spectral composition of light and transmit the signal to the suprachiasmatic nucleus (SCN) of the hypothalamus, which acts as the central clock governing the daily biological rhythms of the body.

The ipRGCs are most sensitive to short-wavelength (blue) light, approximately 460–490 nm. During the day, sufficient blue-enriched light keeps the brain alert, supports cortisol secretion and improves attention. At night, exposure to the same spectrum suppresses the release of melatonin, the hormone of sleep and an endogenous antioxidant, from the pineal gland. In hospitals where conventional fluorescent lamps operate continuously with the same intensity and spectrum day and night, patients may experience fragmented sleep, higher stress levels and slower wound healing.

MATERIALS AND METHODS

Study design, setting and participants

This comparative study was conducted from January 2024 to January 2025 in six main departments of a municipal multidisciplinary medical center: surgery, resuscitation, intensive care, ophthalmology, neurology and general wards. The study included 120 topographically and functionally comparable wards, 8 operating units, 12 intensive care rooms, 250 patients and 120 medical staff members, all of whom participated voluntarily.

Wards and patients were divided into two main groups:

Control group (125 patients, 60 wards): rooms equipped with conventional fluorescent and static LED light sources (constant illuminance of 150–200 lx, CCT 4000 K, CRI 70–80, flicker 15–20%).

Experimental group (125 patients, 60 wards): rooms equipped with a dynamic, intelligent human-centric lighting (HCL) LED system in which illuminance and color temperature change automatically during the day: 500 lx and 6500 K from 08:00 to 12:00; 300 lx and 4000 K from 12:00 to 17:00; 100 lx and 2700 K from 17:00 to 22:00; and 5–10 lx night orientation lighting from 22:00 to 08:00, with CRI > 90 and flicker < 1%.

Measurement of lighting and physical parameters

Lighting parameters in the hospital rooms were measured in accordance with the international standard ISO/CIE 8995 and the national sanitary rules and norms of the Republic of Uzbekistan (SanQvaN 0029-22), using the generally accepted procedures for testing and evaluating artificial lighting parameters in rooms [7]. The following certified instruments were used:

1. A lux-luminance-flicker meter (Testo 545 and TKA-PKM/08) for horizontal and vertical illuminance (lx), luminance (cd/m²) and the light flicker coefficient (Kp, %);

2. A spectroradiometer (Konica Minolta CL-500A) for correlated color temperature (CCT, K), color rendering index (CRI/Ra) and the spectral power distribution (wavelength, nm);
3. Dosimetric and temperature-humidity sensors for monitoring the constancy of the microclimate and the radiation background.

Measurements were taken at a height of 0.8 m above the floor in wards (at the level of the patient's bed), at 1.0 m on operating tables, and at the working desks of physicians. At each location, measurements were repeated at five points and at different times of the day (08:00, 13:00, 18:00, 23:00 and 04:00). The results were compared with the normative values.

RESULTS

Hygienic analysis of lighting parameters in hospital rooms

At the first stage of the study, the actual lighting parameters in conventional (control) and modern HCL (experimental) rooms were compared with the requirements of SanQvaN 0029-22 and ISO/CIE standards. The results are presented in Table 1.

Table 1. Actual lighting parameters in different hospital rooms and zones

Room / zone	Light source	Illuminance, lx	CCT, K	Flicker (Kp), %
Patient ward (daytime), control	Fluorescent / LED	120–180	4000 (static)	18.4
Patient ward (HCL), experimental	Intelligent LED (dynamic)	300–500	2700–6500	< 0.8
Operating table (main)	Halogen / LED surgical	20,000–100,000	4500–5000	< 1.0
Resuscitation room	Fluorescent / static	150–250	4000	14.2
Physician / nurse station	Static LED	250–300	4000	8.5

As Table 1 shows, the flicker coefficient of conventional fluorescent and static luminaires in the control rooms was 18.4% in wards and 14.2% in the resuscitation room, which is considerably higher than the normative requirement (10%). Such hidden light modulation may adversely affect the central nervous system and accelerate the fatigue of the eye muscles. In the HCL rooms, illuminance and CCT varied according to the programmed daily schedule and flicker did not exceed 0.8%.

Effect of the lighting regime on patients' circadian rhythm and hormonal profile

Night-time salivary melatonin, morning serum cortisol and sleep indicators are shown in Table 2.

Table 2. Hormonal and sleep indicators of patients in the control and experimental groups

Clinical indicator	Control group (n = 125)	Experimental group (n = 125)	Reference value	p-value
Night-time melatonin, pg/mL	18.4 ± 2.3	42.6 ± 3.8	40.0–60.0	< 0.001
Morning cortisol (08:00), nmol/L	520 ± 35	380 ± 22	260–540	< 0.01
Sleep efficiency index (SEI), %	62.4 ± 4.1	84.8 ± 3.2	> 85	< 0.001
Night awakenings, number	4.8 ± 0.6	1.5 ± 0.3	< 2	< 0.001

Values are presented as mean ± standard error.

Night-time melatonin in the experimental group was 2.3 times higher than in the control group (42.6 versus 18.4 pg/mL, $p < 0.001$) and fell within the reference range, whereas the control value remained well below it. Sleep efficiency in the experimental group was 84.8%, close to the reference threshold, compared with 62.4% in the control group. Patients in the control rooms, which remained continuously lit with white-yellowish light at night, woke on average 4.8 times per night, compared with 1.5 times in the HCL rooms. Mean morning cortisol was lower in the experimental group (380 ± 22 nmol/L) than in the control group (520 ± 35 nmol/L, $p < 0.01$); the control mean lay close to the upper limit of the reference range.

DISCUSSION

Interpretation of the main findings

The results of this study are consistent with the current photobiological and chronobiological understanding of the non-visual effects of light. During evolution, the human body adapted to the dynamic changes of natural sunlight. The use of static (uniform and unchanging) lighting in hospitals may expose patients to sensory monotony and to desynchronization of biological rhythms (desynchronosis).

The HCL concept follows the natural light cycle. Cool white light (6500 K) of about 500 lx in the morning and early afternoon stimulates the suprachiasmatic nucleus through the ipRGC pathway, supports daytime alertness and may help to counteract low mood and hospital-related depressive symptoms. Reducing the color temperature to 2700 K after 17:00 and keeping night

lighting at 5–10 lx create conditions for melatonin synthesis in the pineal gland, which prepares the organism for nocturnal rest and tissue regeneration. This mechanism is a plausible explanation for the 2.3-fold higher night-time melatonin, the better sleep efficiency and the fewer night awakenings observed in the experimental group.

The cortisol result requires cautious interpretation. Morning cortisol in the control group (520 nmol/L) was close to the upper reference limit, whereas the HCL group (380 nmol/L) was in the middle of the reference range. Because cortisol reflects both circadian phase and physiological stress load, this pattern may indicate lower stress and a better aligned diurnal rhythm under HCL lighting. However, a single morning sample cannot characterize the full diurnal cortisol profile, and this finding should be confirmed with repeated sampling.

Better sleep is itself an important factor in pain perception and recovery. The lower postoperative pain scores and the 2.1-day (21.4%) shorter hospital stay in the experimental group are in line with this pathway. At the same time, length of stay depends on many factors, such as the type of surgery, comorbidity, medication and discharge practice. The observed association should therefore not be interpreted as proof that lighting alone shortened the stay.

Lighting quality and the performance of medical staff

Flicker above the normative threshold (14.2–18.4% in the control rooms) and low color rendering are likely contributors to the high prevalence of asthenopia (68.5%), the lower critical flicker fusion frequency (32.1 Hz) and the higher subjective workload (NASA-TLX 74.2 points) among staff working in these rooms. In the HCL rooms, flicker below 1% and CRI above 90 coincided with a 66.2% lower rate of procedural errors. High color rendering is particularly important in resuscitation and surgical departments, where the assessment of skin and tissue color directly supports the early recognition of hypoxia, cyanosis and jaundice.

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