Studying the Impact of the Light Environment on the Health of Athletes Using the Example of an Educational Institution

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Abstract. The article considers the problem of creating standardized lighting in sports facilities (gym halls). The article assesses the impact made by the reflection coefficients of the surfaces in the room, the chromaticity of the lamp radiation, and the distribution of light from lighting fixtures on the qualitative and quantitative indicators of lighting. The authors have carried out studies of the actual lighting in the premises intended for sports events, as a result of which it has been established that the lighting of sports facilities is an important and difficult task that helps both athletes achieve the desired results and fans who watch spectacular competitions in the stands and on television. Not only the comfort and convenience of athletes, but also the general safety of the participants in the competition, judges and spectators depends on how well the lighting of the stadiums is organized. Correctly selected stadium lighting fixtures play an important role in the presentation of spectacular events, and poor-quality lighting can even affect the course of the game. Therefore, the purpose of this work is to study the impact of the light environment on the health of athletes, in particular, at sports facilities of a higher educational institution. In the course of work, the authors determined the ways of solving the problem. Based on the study of the actual illumination of the playing hall and according to the calculated indicators, we were able to give recommendations for the modernization of the artificial lighting system, namely the use of 36 LED floodlights of the Feron LL-925 2835 SMD 250W 6400K IP65 AC220V/50Hz type. The required power of the developed artificial lighting system will be 9 kW and the purchase of lamps will cost about 350 thousand rubles.

1. Introduction

In the modern world, assessing the parameters of the light environment is an issue just as relevant as the study of radiation, harmful substances, noise and other physical factors affecting the life and health of people. In early times, human labor activity was completely dependent on the length of daylight hours. Nowadays, due to the fact that the normal working activity of a person, in the overwhelming majority, depends on artificial lighting, natural and artificial light is of great physiological importance, especially for lighting sports facilities. Lighting of sports facilities is an important and complex task, which helps both athletes achieve the desired results and fans who watch spectacular competitions in the stands and on television. Not only the comfort and convenience of athletes, but also the general safety of the participants in the competition, judges and spectators depends on how well the lighting of the stadiums is organized. Correctly selected stadium lighting fixtures play an important role in the presentation of spectacular events, and poor-quality lighting can even affect the course of the game. The purpose of this work is to study the impact of the light environment on the health of athletes, in
particular, at sports facilities of a higher educational institution. But, initially, it is necessary to consider what impact the parameters of the light environment have on the health of people in general.

One of the arguments expressed by opponents of assessing lighting conditions in accordance with hygienic standards is the erroneous opinion that there is no scientific evidence on the impact of lighting conditions on the health and performance of workers. At the same time, studies looking into the impact of light on human health and work performance are very numerous both in Russian and foreign science.

GOST 12.0.003-2015 Occupational safety standards system. Dangerous and harmful working factors. Classification specifies the following hazardous and harmful working factors associated with the light environment:

- Lack of necessary natural lighting;
- Lack of necessary artificial lighting;
- Increased brightness of light;
- Reduced light and color contrast;
- Direct and reflected glare;
- Increased pulsation of the light flux.

It has been proven that a low or, on the contrary, an increased level of illumination passing through the retina affects the working processes of the brain and the state of the human body as a whole. Insufficient illumination depresses, decreases work performance, causes drowsiness. This is one of the main reasons for the rapid deterioration of human vision. Too bright light leads to excessive excitement, contributes to the involvement of additional resources of the body, causing their increased wear.

Natural light is most favorable for visual perception and human health. In a natural light environment that is dynamic during the day, there is daily circadian photoperiodism in metabolism, in the release of sleep and wake hormones, in the level of brain activity and other functions of the body of each person. Prolonged exposure to natural light deficiency leads to disruption of physiological balance in the human body and the development of a pathological condition called “light starvation”. It is manifested by a disturbance in carbohydrate, protein, and especially mineral metabolism, with a deterioration in the state of the musculoskeletal system, weakening of immunity to the effects of any pathogenic factors of a bacteriological (viral, bacterial, fungal), chemical, radiation and other nature, as well as by a decrease in the general tone of the body, rapid fatigue, an increase in the number of defects in work and a general deterioration in well-being. The phenomena of “light starvation” observed in the inhabitants of the North and Polar regions are also common in mid-latitudes among people who are partially or completely deprived of natural light during the daytime, i.e. among those working in underground facilities, in above-ground buildings without windows and in buildings with insufficient natural light.

Despite the relatively high levels of illumination created by modern lighting installations, the condition of people performing work under artificial lighting is worse than under natural lighting, as evidenced by the observations of both Russian and foreign researchers. There is a deterioration in well-being, a decrease in work performance, an increase in fatigue, increasing irritability, and frequent headaches.

A huge amount of research has been devoted to the impact of artificial light environment on human performance and health. It should be noted that almost all researchers studied the effect of the artificial lighting level and, in all cases, the quality of illumination (direct and reflected glare, uneven distribution of brightness, pulsation of illumination, spectral composition of lamp radiation, etc.) on performance indicators and human health. Moreover, quite often studies on finding the optimal illumination level for visual performance were carried out in conjunction with the quality of illumination.

Many studies have noted the fact that the quantity and quality of lighting is also very important for low accuracy and rough work; a decrease in injuries is especially noted with favorable lighting. At low light levels, injury can result from both reduced visibility and reduced attention. According to
statistics, on average, for various types of work activities, the number of accidents associated with inadequate lighting is 30-50% of the total. In visual work that does not require high precision, about 1.5% of fatal injuries are due to poor lighting.

The role of the quality of illumination in reducing traumatism can be traced here in all its aspects: direct glare can lead to injury, both due to the glare effect, and as a result of exposure to uneven distribution of brightness in the field of view; increased pulsations of illumination in the presence of moving and especially rotating parts can be dangerous due to the occurrence of a stroboscopic effect. Visual work in conditions of direct glare of light sources leads to significant visual fatigue. The longer the organ of vision is exposed to the glare, the greater its fatigue. Working in conditions of glare leads to a deterioration in performance - a decrease in labor productivity and an increase in rejects. The glare adversely affects the state of the central nervous system, even with an unwearied organ of vision - it reduces the activity of the brain.

In real conditions, the eye detects and discriminates objects, as a rule, against a background of uneven brightness. The negative impact of uneven brightness on the organ of vision is explained by the inductive effect of the visual field periphery, which has a brightness different from that of the center. Studies have shown that when performing visual work associated with the shift of the line of sight, performance decreases if the brightness of the captured surfaces varies significantly. In addition, constant readaptation is accompanied by increased eye fatigue.

Historically, attention was drawn to this indicator only when gas-discharge light sources appeared, and initially the negative impact of the pulsation of illumination was associated with its “visible” manifestation, the stroboscopic effect.

Long-term studies of the impact of light pulsation on human performance and health, carried out by a number of researchers later, have shown that pulsations of the light flux lead to a deterioration in the functional state of the central nervous system, have an adverse effect directly on the nerve elements of the cerebral cortex, which are forced to function in an unusual rhythm of nervous activity, negatively affect the biorhythms inherent in each person, disrupting the activity of the circadian nervous system. The adverse effect of pulsation on the human body increases with increasing of its depth. It causes tension in the eyes, fatigue, difficulty concentrating on complex work, headache. Studies have also revealed an adverse effect of pulsation on the photoreceptor elements of the retina, causing their demobilization and disabling due to irritation. The pulsation of illumination worsens not only the functional state of the visual analyzer, but also the general performance of a person.

It is no coincidence that such a large number of scientific studies are devoted to the issues of the impact of light environment indicators on human health. Based on these studies, lighting regulations are being developed in all countries. GOST 24940-96 became the first document regulating illumination measurements in Russia. It covered a large number of concepts associated with lighting. Among such concepts are illumination, average, minimum and maximum illumination, cylindrical illumination, natural illumination coefficient (NIC), safety factor, relative spectral luminous efficiency of monochromatic radiation. But due to the relevance of illumination measurements and related concepts, the standard was supplemented and revised. To supplement the outdated GOST, new standards GOST R 54944-2012 and MUK 4.3.2812-10 were developed. These regulatory documents included such concepts as emergency lighting, security lighting, work lighting, reserve lighting, semicylindrical illumination, and evacuation lighting.

In addition, the lighting regulations in force in the Russian Federation (SP 52.13330.2016. Set of rules. Natural and artificial lighting. Updated revision of SniP 23-05-95*, GOST R 55710-2013. National standard of the Russian Federation. Lighting of workplaces inside buildings. Norms and methods of measurements, SanPiN 2.2.1/2.1.1.1278-03. Hygienic requirements for natural, artificial and combined lighting of residential and public buildings), along with the requirements for natural lighting, contain requirements for both the level of illumination and the quality indicators of artificial lighting. In particular, more detailed requirements related to sports facilities are standardized by SP 440.1325800.2018 Sports facilities. Designing natural and artificial lighting. Let us consider the
procedure for studying the parameters of the light environment using the example of a sports facility in a higher educational institution.

2. Study objects and methods
As the object of research, we chose a sports facility of one of the higher educational institutions in the city of Irkutsk. The sports facility is an indoor sports venue designed for educational and sports work, training and competitions at the regional and all-Russian level. The facility is 10 m high, 50 m long and 18 m wide. The existing artificial lighting system is presented in the form of 34 RKO-250 lighting fixtures with LED HP lamps, located at a height of 9.5 m and 10 fluorescent lighting fixtures with two LB-40 lamps in each, located at a height of 3.5 m on one of the walls along the entire the length of the room. The existing lighting system has been repeatedly criticized by students and employees of the institution. The main complaint is the lack of lighting in the evening and at night. To solve this problem, we carried out a set of works to determine the actual parameters of the light environment and develop measures to improve the existing artificial lighting system.

To establish the values of the main parameters of the light environment, they were measured, in particular, artificial illumination and pulsation coefficients. The measurements were made using equipment belonging to the Research Laboratory of Industrial and Fire Safety of Irkutsk National Research Technical University, and namely, using an Ecolight luxmeter-brightness meter-flicker meter to measure illumination and pulsation coefficient. The work was carried out based on the procedure FR.1.37.2013.14755 Procedure for measuring illumination parameters with an Ecolight-01 luxmeter-brightness meter-flicker meter. For the measurement, we selected 30 points distributed throughout the room. Based on SP 440.1325800.2018, the measurements were made at a height of 0 m (on the floor, the photohead was placed horizontally) and 2 m (vertically, on both sides on the longitudinal axis of the room).

The development of measures to normalize the parameters of the light environment was reduced to the calculation of an artificial lighting system. There are various methods for calculating artificial lighting, which can be reduced to three main ones: point method, method of utilization of the light flux and method of specific power.

The point method is designed to find the illumination at the calculated point; it is used to calculate the illumination of arbitrarily located surfaces for any illumination distribution. The reflected component of the illumination in this method is taken into account approximately. The point method calculates general localized illumination, as well as general uniform illumination in the presence of significant shading.

The most common in design practice is the method for calculating artificial lighting using the method of utilization of the light flux. The utilization of the light flux (or lighting installation) is usually understood as the ratio of the light flux falling on the design plane to the light flux of light sources. The utilization of the lighting installation, which characterizes the efficiency of using the light flux of light sources, is determined, on the one hand, by the light distribution and placement of lighting fixtures, and, on the other, by the ratio of the dimensions of the illuminated room and the reflective properties of its surfaces.

The method of specific power is used to preliminary determine the power of the installed lighting installation or to roughly estimate the correctness of the calculation performed. It is based on the average values of the power required to create the required illumination at average values of the lighting installation utilization. The essence of calculating lighting using the specific power method is that the value of the specific power is determined depending on the type of lighting fixtures and the place of their installation, the height of the suspension above the working surface, illumination, illumination on the horizontal surface and the area of the room.

3. Results and discussion
In the work, we used a calculation method based on the utilization of the light flux. The calculation of the artificial lighting system was carried out according to the calculation method given in the Manual
to MGSN 2.06-99 *Calculation and design of artificial lighting in public buildings* and the following algorithm:

1. Selecting the standardized value of illumination \( E_n \) depending on the intended use of the room.
   In accordance with clause 1 of the Table 5.3, for rooms characterized as halls for sports games and multifunctional sports halls, the standardizes value on the floor \( (G = 0.0) \) with a general lighting system \( E_n = 300 \text{ lux} \).

2. Determining the height of the lighting fixture suspension above the working surface:
   \[
   H_p = H - (h_c + h_w),
   \]
   where \( H \) is the height of the room, m;
   \( h_c \) is the height of the lighting fixture suspension from the ceiling, m;
   \( h_w \) is the working surface height, m.

3. Determining the index of the room:
   \[
   i = \frac{AB}{H_p \cdot (A + B)},
   \]
   where \( A \) is the length of the room, m;
   \( B \) is the width of the room, m.

4. Selecting the reflection coefficients of the ceiling \( \rho_{cnor} \), walls \( \rho_{cr} \) and floor \( \rho_{pol} \) in the room.

5. Determining the utilization of the light flux \( \eta \) depending on the room index \( i \), the reflection coefficients and the type (group) of the lighting fixture.

6. Determining the safety factor \( K_z \) depending on the operating factor. The operating factor \( MF \) for the room under consideration is determined in accordance with Table 4.3 in SP 52.13330.2016 *Natural and artificial lighting*.

7. Determining the required light flux:
   \[
   F = \frac{E_n \cdot S \cdot K_z \cdot Z}{N \cdot \eta},
   \]
   where \( S \) is the area of the room, m\(^2\);
   \( Z \) is the coefficient of variation depending on the type of lamps;
   \( N \) is the estimated number of lighting fixtures, pcs.

8. Determining the standard light flux for the lamp.

9. Comparing the standard light flux of the selected lamp with the required light flux and determining the degree of deviation between them using the formula
   \[
   \left( \frac{F_{im} - F}{F_{im}} \right) \cdot 100\%.
   \]
   The identified degree of deviation of the light flux of the selected lamp type must correspond to the permissible limit (from –10% to +20%).

### 4. Conclusion

According to clause 1 of the Table 5.3 in SP 440.1325800.2018 *Sports facilities. Designing natural and artificial lighting*, the measured illumination values do not meet regulatory requirements at all measurement points. The pulsation coefficient indicators do not correspond to the regulatory requirements at the measuring points No. 1 and No. 26. To illuminate the playing hall up to the established regulatory level for artificial illumination (300 lux on the floor) established by SP 440.1325800.2018 *Sports facilities. Designing natural and artificial lighting*, it is recommended to upgrade the lighting system by using 36 LED floodlights of the Feron LL-925 2835 SMD 250W
6400K IP65 AC220V/50Hz type. The required power of the developed artificial lighting system will be 9 kW and the purchase of lamps will cost about 350 thousand rubles.

Ensuring proper lighting conditions for workplaces, and, consequently, maintaining human health requires strict compliance with all regulatory requirements for the light environment indicators, which is dictated by the provisions of the Federal Law No. 52-FZ “On the Sanitary and Epidemiological Welfare of the Population”. It is impossible to assess the lighting conditions of the workplace only by the level of illumination. The parameters of the lighting quality (in particular, glare, pulsation of illumination, etc.), along with illumination, are just as important for characterizing the light environment, both from the point of view of creating the required conditions for the eye, and the effect on human health in general.

5. References
[1] Gaston K J, Visser M E, Holker F 2015 The biological impacts of artificial light at night: the research challenge Phil. Trans. R. Soc. B 370 20140133
[2] Stevens R G, Zhu Y 2015 Electric light, particularly at night, disrupts human circadian rhythmicity: is that a problem? Phil. Trans. R. Soc. B 370 20140120
[3] Walker W H, Bumgarner J R, Walton J C, Liu J A, Meléndez-Fernández O H, Nelson R J, DeVries A C 2020 Light Pollution and Cancer International Journal of Molecular Sciences 21:24 9360
[4] Rhudy M B, Greenauer N, Mello C 2020 Wearable light data logger for studying physiological and psychological effects of light data HardwareX 8 e00157
[5] Saw Y J, Kalavally V, Tan C P 2020 The Spectral Optimization of a Commercializable Multi-Channel LED Panel With Circadian Impact IEEE Access 8 136498-136511
[6] Mouland J W, Martial F, Watson A, Lucas R J, Brown T M 2019 Cones Support Alignment to an Inconsistent World by Suppressing Mouse Circadian Responses to the Blue Colors Associated with Twilight Current Biology 29:24 4260-4267
[7] Petrowski K, Schmalbach B, Niedling M, Stalder T 2019 The effects of post-awakening light exposure on the cortisol awakening response in healthy male individuals Psychoneuroendocrinology 108 28-34
[8] Zhong C, Franklin M, Wiemels J, McKean-Cowdin R, Chung N T, Benbow J, Wang S S, Lacey J V, Longcore T 2020 Outdoor artificial light at night and risk of non-Hodgkin lymphoma among women in the California Teachers Study cohort Cancer Epidemiology 69 101811
[9] Lu X, Park N-K, Ahrentzen S 2019 Lighting Effects on Older Adults’ Visual and Nonvisual Performance: A Systematic Review Journal of Housing For the Elderly 33:3 298-324
[10] Smolensky M H, Hermida R C, Reiner A, Sackett L, Portaluppi F 2016 Circadian disruption: New clinical perspective of disease pathology and basis for chronotherapeutic intervention Chronobiology International 33:8 1101-1119
[11] Fernandez R C, Moore V M, Marino J L, Whitrow M J, Davies M J 2020 Night Shift Among Women: Is It Associated With Difficulty Conceiving a First Birth? Frontiers in Public Health 8 595943
[12] Pakiarian D, Rudolph K E, Stapp E K, Dunster G P, He J, Memmert D, Hattar S, Casey J A, James P, Merikangas K R 2020 Association of Outdoor Artificial Light at Night With Mental Disorders and Sleep Patterns Among US Adolescents JAMA Psychiatry 77:12 1266
[13] Esaki Y, Obayashi K, Saeki K, Fujita K, Iwata N, Kitajima T 2020 Effect of evening light exposure on sleep in bipolar disorder: A longitudinal analysis for repeated measures in the APPLE cohort Australian & New Zealand Journal of Psychiatry 29 000486742096888
[14] Franklin M, Yin X, McConnell R, Fruin S 2020 Association of the Built Environment With Childhood Psychosocial Stress JAMA Network Open 3:10 e2017634
[15] Lai K Y, Sarkar C, Ni M Y, Gallacher J, Webster C 2020 Exposure to light at night (LAN) and risk of obesity: A systematic review and meta-analysis of observational studies *Environmental Research* **187** 109637