Original Article

Journal of Occupational Health and Epidemiology

Journal Homepage: https://johe.rums.ac.ir/

JOHE

Rafsanjan University of Medical Sciences

The Effect of Different Light Intensities on Oxidative Stress Biomarkers: An Experimental Study

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Citation: Yekzamani P, Alimohamadi I, Abolghasemi J, Masruri B, Ashtarinezhad A. The Effect of Different Light Intensities on Oxidative Stress Biomarkers: An Experimental Study. J Occup Health Epidemiol. 2023;12(2):123-9.

Article Info

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Article history
Received: Mar 2022
Accepted: Apr 2023

10. 61186/johe.12.2.123

Print ISSN: 2251-8096
Online ISSN: 2252-0902

Peer review under responsibility of Journal of Occupational Health and Epidemiology

Abstract

Background: Light can be considered as one of the factors affecting performance, visual comfort, proficiency, and energy efficiency in the workplace. This study aimed to investigate the oxidative stress-induced light intensity in male rats.

Materials and Method: In this experimental study, a total of 32 male rats were randomly divided into four groups of eight (control group: exposure to 150 lux, group 2, 3, and 4 exposure to 300, 5000, and 8000 lux, respectively). Blood samples were collected from each rat before, 7, and 14 days after exposure. Malondialdehyde (MDA) and Total Antioxidant Capacity (TAC) levels were measured as oxidative stress indices. Data were analyzed using SPSS software.

Results: The results showed that the intensity of 8000 lux increased the MDA level and decreased the TAC level 7 and 14 days after exposure. The TAC level decreased in the group exposed to 5000 lux light intensity during 7 and 14 days (0.31±0.065 mmol/L and 0.36±0.077 mmol/L, respectively). The 5000 and 8000 lux light intensities decreased the TAC and caused oxidative stress in male rats after 7 and 14 days, and only the group exposed to 300 lux light intensity can restore TAC to normal levels since the 7th day.

Conclusion: The results of this study showed that light intensity is a significant factor in the development of oxidative stress. It seems that higher light intensities along with 14 days have more effects on the oxidative stress.

Keywords: Oxidative Stress, Malondialdehyde, Antioxidant, Lighting

Introduction

Environmental lighting includes natural and artificial lighting [1]. For over 500 years, the visual effects of light have been studied by researchers [2]. However, human knowledge of the effects of artificial light on health is still limited. The increasing use of artificial light for a significant portion of daily duties makes a better understanding of its effects necessary [3, 4]. Adequate lighting is an important and essential factor in visual work [5]. Lighting affects the physiological and biological processes in the body [6] .Hence, it has become the subject of many studies in the world [2]. Light wavelength and

intensity, or exposure duration, can lead to changes in the endocrine and physiological processes of the body [7]. Lighting standards in residential, commercial, public, and industrial environments have been specified to comfort people with luxury units. For residential environments, the standard criterion of light intensity is between 100 and 500 lux, and for office places, 150 and 500 lux. The standard for roofing and normal work is 200-300 lux, and 300-500 lux for precise work. The more accurate the work, the more lighting intensity is needed, so the lighting intensity is 1000 lux for the drawing table and 1000 lux for the operating room on the surgical table. 8000 lux is suggested [8]. Light can be considered as one of the factors affecting performance, visual comfort, proficiency, and energy efficiency in the workplace [9]. Proper lighting has positive effects on the level of consciousness, health, sleep quality and well-being of individuals [2]. High light levels cause fatigue, headache, stress, anxiety and eye irritation [10], and have negative impacts on ecosystem health [3]. On the other hand, low light levels exert negative effects, including headaches, dizziness, increased intraocular pressure, musculoskeletal disorders, and fatigue [10]. Exposure to visible light can produce some reactive oxygen species (ROS)[11] containing superoxide (O2-), hydrogen peroxide (H2O2), hydroxyl radicals (OH-), oxygen radical (O2) [12, 13], which are produced in the endoplasmic reticulum, cell membrane, peroxisome [14], and mitochondrion [14, 15] by normal cellular metabolism as well as inflamed cells [7]. A free radical is a molecule with an unpaired electron in the outmost orbital [16]. An unpaired electron causes instability and, therefore, high activation of the molecule or atom. When the level of peroxides exceeds the ability of the antioxidant defense system, oxidative stress occurs [17].

Among oxidative stressors, It may mention radiation, vibration, cold, heat, lead, mercury, cadmium, solvents, environmental pollution, pesticides, and stress [18, 19]. The excessive increase in ROS leads to damaged lipids [14], proteins [17], and DNA [17, 19, 20], ultimately resulting in cell death [17] and destruction of body tissues and organs [14]. It is one of the factors contributing to diseases such as neurological disorders, cancer, heart damage [21], and premature aging [21, 22]. The study of Tian H-Y on fish species (juvenile blunt snout bream Megalobrama amblycephala) revealed that the antioxidant enzyme activity increases with exposure to 800 and 1600 lux light [23]. Due to the lack of studies on the effect of light intensity on oxidative stress biomarkers, the study conducted on a fish sample is given only to show the effect of light intensity on oxidative stress. The results of a study by Wang T showed that the activity of superoxide dismutase (SOD) and nitric acid content (NO) was significantly higher in the group exposed to light intensity of 600-1150 lux [24].

Also, The results of Farooqui MY revealed that liver lipid peroxidation showed an increasing trend during the light cycle and a decreasing trend during the dark cycle [25]. Considering the importance and role of light as a physical factor affecting productivity, reducing human error and musculoskeletal disorders, and the effects of it on oxidative stress biomarkers and conflicting results about the effect of different light intensities on these biomarkers, also, according to the few studies conducted in the field of jobs such as surgery operation and work outdoor that exposure to high light intensity, we considered it necessary to conduct this study.Therefore, this work aimed to investigate the effect of different light intensities on oxidative stress in male rats.

Materials and Methods

This experimental study was conducted in a chamber dimensioned of 80*80*95 designed so that the rats would be exposed to artificial light of 300, 5000, and 8000 lux.

Covering the walls of the room prevented the interference of natural and artificial environmental light with the chamber. LED lamps quickly replaced incandescent lamps as one of the lighting sources with two characteristics of: low consumption and relatively long life. Although these lamps changed the lighting industry, their threat to people's health is a question that has occupied the medical community. Considering the danger these lamps have for health and also according to several studies that have investigated the effect of these lamps on the level of oxidative stress biomarkers, we have used this type of lamp in this study [12, 26]. The lamps were designed at a height of 80 cm from the rats. A thin cloth was placed between the lamps and the cages, and the mean light intensity was measured using the HAGNER EC1 (PATENT NO.80, 503, 358-7) lux meter.

The choice of animal sample size was under previously similar articles in which the rats participated in the interventional studies [25, 27].

Inclusion criteria: In this study, we used male Wistar rats weighing 220-300 gr.

Exclusion criteria: Female rats and animals weighing less than 220-300 gr.

32 healthy male Wistar rats were randomly divided into 4 (n=8 in each group). They were kept in a chamber with the environmental conditions of 22 ±

2 ° C temperature, 12: 12 light percentage, with free access to water and food, one week before the test to habituate to the new environment [25]. All test and experimental procedures were performed conforming to the ethical standards and guidelines approved by ethics committee, Iran University of Medical Sciences (approval #: IR. IUMS. REC. 9411139011). Group 1, considered the control group, was exposed to 150 lux light intensity (Minimum light in office and residential places). Groups 2, 3, and 4 were exposed to the light intensity of 300, 5000, and 8000 lux for 7 and 14 days. The dark-light cycle of 12-12 dark/ light cycles (light cycle from 7:00 am to 7:00 pm, dark cycle from 7:00 pm to 7:00 am) was set by placing a timer on the power input to the chamber. The rats in all groups were anesthetized with ketamine (50-100 mg/kg) and xylazine (5-10 mg/kg) on the first day (before the test), and 7 and 14 days after exposure. The blood samples from the heart were poured into tubes containing Ethylenediaminetetraacetic acid (EDTA) and centrifuged at 3000-2000 rpm for 10 minutes. The plasma was then isolated and placed at -80 ° C until it was analyzed.

Measurements of oxidative stress Biomarkers: The plasma MDA level was measured using a Malondialdehyde Assay Kit (zellbio GmbH Germany) according to the manufacturer's instructions based on the reaction of malondialdehyde with thiobarbituric acid at high temperature and formation of pink color at the wavelength of 545 nm with an ELISA device (stat fax-2100, USA). The MDA value was expressed in µmol/L.

The plasma TAC level was measured using the Total Antioxidant Capacity Assay Kit (zellbio GmbH Germany) according to the manufacturer's instruction based on colorimetric oxidation reduction at the 490 nm wavelength with an ELISA device (BIORAD 680, Japan). The result was expressed in mmol/L.

Measurements of TAC and MDA level were according to the manufacturer's instructions.

All data was analyzed by Prism software. The Kolmogorov-Smirnov test was used to check the variables for normality. Statistical analysis of variance (ANOVA) and Bonferroni posthoc tests were applied to analyze the intergroup differences of normal data and Paired –Samples T-test for data average on different days in each group. The significance level (P-values) was < 0.05.

Results

Effect of different light intensities on TAC changes after 7 days of exposure: Table 1 shows the average TAC level in the three exposure groups and the control group on the first day (before exposure) and 7 and 14 days after exposure. The results revealed significant differences between the four groups after 7 days of exposure. Changes in the TAC level were reduced significantly in the groups exposed to 300, 5000, and 8000 lux compared to the control group (p-value< 0.05, p-value< 0.001, and p-value<0.001, respectively). The group exposed to 5000 lux was not significantly different from those exposed to 300 and 8000 lux light intensity. The decrease in TAC level was higher in the group exposed to 8000 lux than in the group exposed to 5000 lux (Fig.1).

Table 1 . Plasma TAC level on different days of exposure (N=8)

Groups	TAC (Before exposure) mmol/ L	TAC（After 7 days ） mmol/ L	TAC（After 14 days） mmol/ L
Control	0.51±0.34	0.61±0.32	0.61±0.31
300 lux	0.29±0.011	0.24±0.016	0.33±0.025
5000 lux	0.46±0.10	0.31±0.065	0.36±0.077
8000 lux	0.51±0.069	0.35±0.037	0.32±0.053

Data expressed as mean ± SD

Effect of different light intensities on TAC changes after 14 days of exposure: The results showed significant differences in TAC level changes among the groups within 14 days of exposure. The group exposed to 300 lux light was not significantly different in TAC changes compared to the control group within this period. Although the TAC level decreased significantly in the group exposed to a light intensity of 300 lux during the first seven days, it increased from day 7 to 14. It did not show a significant difference with the control group. TAC levels decreased significantly in the group exposed to 8000 lux (p-value<0.001) and 5000 lux (p-value<0.001) during 14 days of exposure compared to the control group. After 14 days of exposure, there was a significant difference in TAC level between the group exposed to 300 lux one hand. Still, there was no notable difference between the group exposed to 5000 lux and the group exposed to 8000 lux.

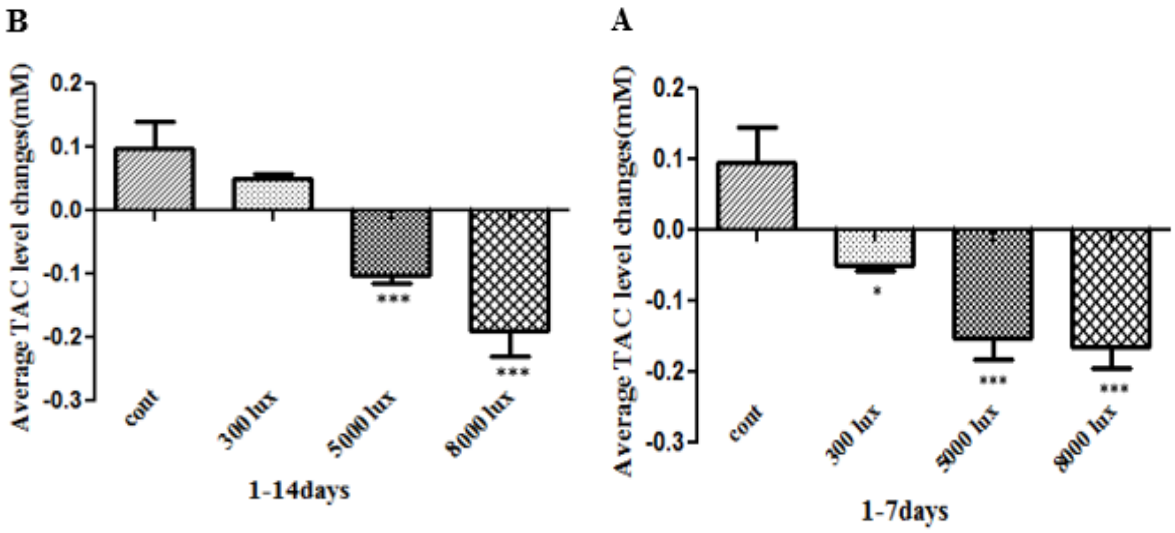

Fig. 1. Effect of various light intensities on oxidative stress. Data are expressed as mean ± SD (n = 8).

Effect of different light intensities on MDA level after 7 days of exposure: Table 2 shows the MDA levels in different groups before exposure and on days 7 and 14. The results showed that although the MDA levels increased insignificantly in the three groups from days 1-7, only the group exposed to 8000 lux decreased significantly compared to the control group (p-value 0.05), and there was no significant difference in other groups during the first seven days of exposure (Fig. 2).

Effect of different light intensities on MDA level after 14 days of exposure: Plasma MDA level increased significantly in the group exposed to a light intensity of 8000 lux within 14 days of exposure as compared to the control group and the group exposed to 300 and 5000 lux light intensity (p-value ≤0.001). Although MDA levels decreased insignificantly in the group exposed to 300 and 5000 lux after 14 days of exposure, they were not significantly different from each other and the control group (Fig. 2).

Table 2. Plasma MDA level on different days of exposure (N=8)

Groups	MDA (Before exposure) µmol / L	MDA（After 7 days ） µmol / L	MDA（After 14 days） µmol/ L
Control	29.10±4.51	27.7±4.23	27.44±3.85
300 lux	31.29±3.27	32.49±4.08	30.27±4.53
5000 lux	23.83±3.73	25.10±2.59	20.0±3.55
8000 lux	20.89±3.17	23.50±3.04	32.57±6.10

Data expressed as mean ± SD

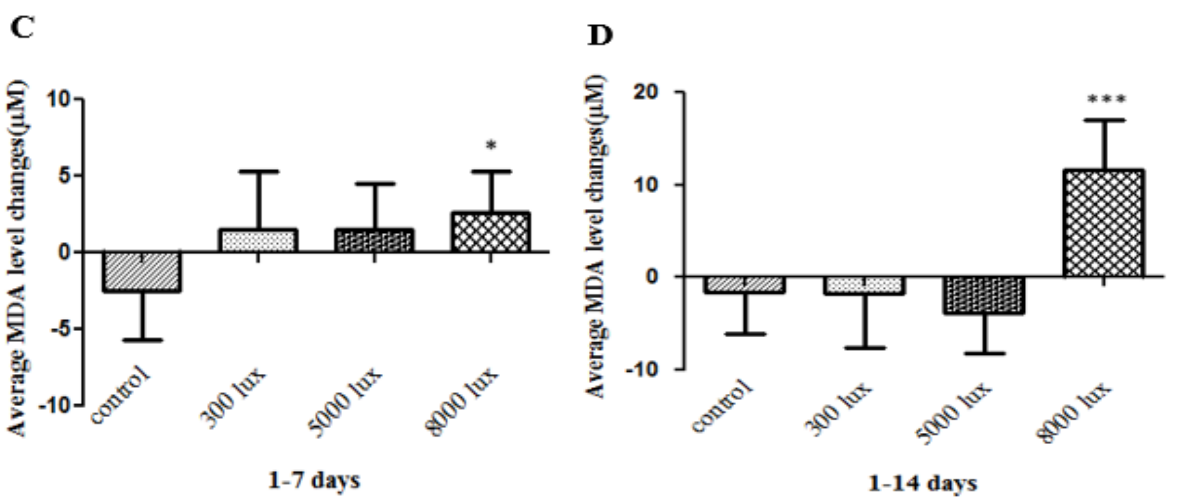

Fig. 2. Effect of various light intensities on oxidative stress. Data are expressed as mean ± SD (n = 8).

Discussion

To date, human knowledge on artificial light's effects on the ecosystem is still limited, and few studies have been conducted on the effects of light intensity on oxidative stress. In contrast, with the growing use of artificial light, a better understanding of its effects is necessary [4]. This study investigated changes in TAC and MDA levels as oxidative stress biomarkers under different light intensities. It showed that plasma TAC levels decrease with an increase in the light intensity within seven days of exposure (Fig. 1). In line with this study, the effect of visible light toxic on E.coli revealed a relationship between light intensity and toxicity. Exposure to visible light produces active oxygen species and damages certain proteins [11]. Normally, there is a balance between the generation and disposal of free radicals in the body, and the enzymatic and non-enzymatic antioxidant defense system confronts ROS. Still, any endogenous or exogenous factor that interferes with this balance and increases active oxygen species can lead to oxidative damage to the tissue [13]. It is accepted that the ROS generated in the tissues exposed to light leads to biological changes in that tissue [1]. The results of a study of a fish species under light densities of 0, 10-50, 320-550, 600-1150, and 3000-3500 lux showed that the light intensity of 600-1150 lux increases the activity of total superoxide dismutase [24]. The results of our study also showed that the amount of TAC in the group exposed to the light intensity of 300, 5000, and 8000 lux decreased after 7 days of exposure and led to oxidative stress. Our study revealed that light intensity is a significant factor in the incidence of oxidative stress during the first seven days of exposure.

It has been reported that the DNA in human retinal epithelial cells will be damaged after three hours of exposure to visible light because of the production of singlet oxygen, anion superoxide, and radical hydroxyl in the mitochondria. After 6 hours of exposure, less damage is observed due to DNA repair, indicating an adaptive response to the oxidative load [28]. In the present study, the plasma TAC level increased in the group exposed to a light intensity of 300 lux from the seventh day onwards. This seems to be due to the prominence of rats' antioxidant defense systems to oxidative stress. The TAC level begins to increase from the seventh day, and the equilibrium between the oxidant and antioxidant defense system is restored (Fig. 1). The TAC level revealed a decrease after 14 days in the group exposed to 5000 and 8000 lux intensities. It seems that high light intensities have a greater effect on oxidative stress.

When free radicals attack unsaturated fatty acid in the cell membrane, lipid peroxidation occurs [29], and MDA is produced in the cell as a lipid peroxidation biomarker [30]. An Increase in the generation of free radicals at high light intensity levels leads to an increase in the MDA levels. The study of the effect of different light intensities on the changes of some oxidative stress biomarkers in a fish species showed that the light intensity of 800 lux and 1600 lux significantly increased the activity of superoxide dismutase and glutathione peroxidase and that the activities of the liver catalase and MDA decrease at intensities of 100, 200, and 400 lux, and increase significantly at 800 and 1600 lux [23]. Radiation of LED lamps in mammalian cells has been reported to increase the production of free radicals and lipid peroxidation [1].

The study of rat liver tissue showed that glutathione levels decreased during the light cycle and increased during the dark cycle, while MDA levels showed the opposite result [25]. Glutathione plays a role in the body's antioxidant defense system through confrontation with ROS [31] and is a potent inhibitor of lipid peroxidation. A decrease in glutathione levels is associated with increased lipid peroxidation levels [25]. Also, the study results of a species of fish showed that the increase in stress responses with increasing light intensity might be due to increased levels of glucose, lactate, and cortisol [23]. Our study also suggests that increased MDA level under the light intensity of 8000 lux after 7 and 14 days of exposure may have been due to increased free radicals and decreased glutathione levels. This light intensity seems to result in a release of free radicals to the extent that the antioxidant system of the rat's body is not able to restore MDA to normal levels from the seventh day afterward. But MDA level in the group exposed to 5000 lux and 300 lux light intensity did not change significantly compared to the control group after 7 and 14 days of exposure. It seems that the light intensity of less than 8000 lux had no significant effect on plasma MDA level changes in male rats (Fig. 2). A study of E.coli in seawater using a 20 W fluorescent lamp showed that the distribution of fatty acids did not change significantly after exposure to visible light [11]. Therefore, we assume that lighting is a physical factor causing oxidative stress in male rats. This stress disturbs the balance between the production and the destruction of ROS, leading to a decrease in antioxidant capacity and an increase in lipid

peroxidation under high light intensities. Our study had some limitations, such as LED lamp failure, lack of studies about the effects of light on rats, animal death, and so on.

Conclusion

This study showed that light intensity is a significant factor in the development of oxidative stress, which leads to a decrease in TAC levels in male rats during seven days of exposure. The return of the plasma TAC to normal levels at 300 lux light intensity since the seventh day indicates that this intensity has less impact on the development of oxidative stress compared to other intensities in this study and that it is beneficial for the biological and physiological systems of the body. An increase in the MDA levels does not accompany the increase in light intensity, and only a light intensity of 8000 lux leads to a significant increase in lipid peroxidation. Therefore, low light intensity plays a smaller role in the development of oxidative stress. Human studies using the results of animal models are recommended to study these effects on humans as closely as possible in future research.

Acknowledgement

We would like to thank the toxicology laboratory at the Iran University of Medical Sciences and Comper Studies for their cooperation in this study.

Conflict of interest: None declared.

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