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RESEARCH LETTER

Skin and scalp under exposure to high-energy visible light: the current perspective

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The sun is a powerful source of light, ultraviolet (UV) and high-energy visible (HEV) light, which both have positive and negative effects on overall health. In the visible light spectrum, HEV light is a high-energy form with a short wavelength ranging from approximately 380–480 nm (nm). It is also emitted by electronic devices, such as computer screens, smartphones, and tablets. Consequently, the influence of environmental blue light on human health and its potential impacts necessitates a summary and compilation of existing evidence.

1. High-energy visible light, oxidative and nitro-oxidative stress, and DNA modyfications

The destructive effect of both HEV and UV radiation is mainly related to the activation of mechanisms triggered by direct photochemical action, generated by reactive oxygen (ROS) and nitric oxide (NO). This oxidative damage has the potential to set off a chain of events leading to cellular malfunction and may impact several physiological functions [1]. The results of the study by Barolet et al. show that HEV light at different wavelengths can induce varying degrees of intracellular oxidative stress with different physiological effects [1]. The danger of ROS overproduction is mainly caused by their ability to interact with DNA molecules and thus induction of mutagenesis [2–4]. According to the current research, the HEV light emitted in low doses may cause disadvantageous effects that contribute to the accumulation of mutations in skin cells [2]. In vitro studies by Chamayou-Robert and DiGiorgio et al. performed on keratinocytes reported that irradiation with 415 nm HEV light doses of 4.8, 9.6, and 14,4 J/cm^2 induces DNA damage leading to chromosomal aberrations. On the other hand, the HEV light may influence mitochondrial activity via cytochrome C oxidase which is located in the mitochondrial membrane [2]. At a wavelength of 430 nm it reactivates the mitochondrial respiratory function inhibited by NO [5–7]. An in vivo study based on the measurement of carotenoids in the skin also indicated the formation of free radicals after HEV irradiation [7]. The increase in the irradiation dose promoted the degradation of carotenoids in the epidermis and increased their regeneration time. Moreover a dose-dependent decomposition of antioxidants in the epidermis was observed [7]. The study confirmed the finding that NO generation by HEV light also takes place through non-enzymatic pathways. Thus, it includes photolysis, influences vasodilation, and causes an increase in the local blood flow [1]. High-energy visible light irradiation results in NO translocation from the dermis into the underlying tissue. The NO may then react with superoxide to form peroxynitrite, which may cause DNA damage; however, apoptosis was not observed [6].

2. High-energy visible light and cicardian rhytms

Many researchers have investigated the specific effects of HEV light–induced DNA damage on the disruption of circadian rhythms [1, 8]. Chronic exposure to the HEV light has an inhibitory effect on melatonin synthesis and disrupts the circadian rhythm of the body, which may

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be a predisposing factor for faster aging process [9, 10]. Melatonin is the most intensively secreted by the pineal gland, as a response to a decrease in the surrounding light intensity, and non-specifically acts as an antioxidant on the skin [9]. At the level of gene transcription, melatonin increases the expression of antioxidant enzymes genes and reduces the expression of pro-oxidative enzymes genes. It can be concluded that, by limiting the metabolic functions of melatonin, the HEV light exposure during the dark phase of the day can exacerbate diseases such as psoriasis and atopic dermatitis [9]. This is proved by the increased concentration of pro-inflammatory cytokines in the plasma and the increased expression of TNF-α [9, 11]. Several current studies revealed a correlation between HEV disturbance in circadian rhythm and dysfunction of the hypothalamic–pituitary–adrenal axis [12, 13]. The changes are then recognized in glucocorticoid levels, elevated blood insulin levels, and decreased tissue sensitivity to glucose. The above factors play an important role in the pathogenesis of skin diseases and androgenetic alopecia.

3. High-energy visible light and cortisol

One of the stress-related hormones, cortisol, is known to influence the function and cyclical regulation of hair follicles High levels of cortisol were shown to reduce the synthesis and accelerate the degradation of important skin components, particularly hyaluronan and proteoglycans, by approximately 40%. Thus, excess cortisol can disrupt the precise mechanism of HF, leading to the development of hair growth disorders such as androgenetic alopecia, alopecia areata, and telogen effluvium [14, 15]. Moreover, high levels of cortisol in the blood lead to immunosuppression, as observed during the course of atopic dermatitis or psoriasis. In addition, high levels of cortisol intensify the work of the sebaceous glands, thus contributing to the formation of seborrhea. Although HEV light can damage the skin in several ways, recent research suggests that it could support the treatment of some skin dermatoses. Buscone et al. reported that the exposure of the human scalp hair follicle to HEV light (453 nm) led to intra-alveolar accumulation of the cryptochrome 1 (CRY1) protein [16]. The CRY1 protein is stimulated by KL001, a protein that can regulate metabolic processes related to the circadian rhythm. CRY1 stimulation prolongs anagen, while CRY1 silencing promotes ex vivo catagen development. The authors also found that the CRY1 protein was clearly expressed in human scalp hair follicles during anagen, particularly in stem cells and progenitor cells. This finding is consistent with the notion that the HEV light stimulation of hair growth is mediated at least in part by CRY1 [16].

4. Future perspective

It should be emphasized that research suggests contingent upon irradiance and intensity, HEV light does not significantly induce oxidative stress. Based on reviewed studies, it can be concluded that HEV at different wavelengths induces varying degrees of intracellular oxidative stress with different physiological effects. The main mediators of cellular responses to the HEVlight are NO and ROS. Literature indicates also that HEV light influences melanin production pathways, which causes disrupting the circadian rhythm.

On the other hand, it should be highlighted that HEV light has a beneficial application in dermatological treatments and cosmetology. It has also proven effective for use in the treatment of acne, psoriasis, keratoris, and alopecia areata by reducing inflammation and promoting skin healing. Therefore, it appears that the benefits outweigh the potential risks of scalp keratinocyte DNA modifications.

However, the results of other studies demonstrate that the HEV light may accelerate the aging process. Consequently, it is crucial in the therapeutic context to consider the relationship between the intensity and duration of scalp exposure and melanin biosynthesis. Therefore, it is imperative to establish safety rules delineating the duration, intensity, and frequency of HEV blue light lamp usage. Overall, more research is needed to evaluate the effects of cumulative exposure to the low doses of blue light on the human body. A comprehensive review is necessary due to reports concerning the impact of blue light emitted by electronics. It is evident that the duration of exposure to radiation emitted by surrounding devices has significantly more severe consequences than the use of blue light in appropriate doses and durations for prospective therapies.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interest The authors declare no competing interests.

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