PREGLEDNI RAD

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UTICAJ PLAVE SVETLOSTI IZ PRIRODNIH I VEŠTAČKIH IZVORA NA KOŽU

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SAŽETAK

Plava svetlost obuhvata zrake manje energije u odnosu na UV zračenje, ali ima veću moć prodiranja u dermis, čak do dubine od 1mm. Cilj ovog preglednog rada je bio da se na osnovu dostupne literature analiziraju biološki efekti prirodne i veštačke plave svetlosti na kožu, kao i da se predlože preventivne mere za zaštitu kože od njenih štetnih efekata. Najnovija istraživanja ukazuju da plava svetlost ima različite direktne i indirektne efekte na kožu. Direktni efekti plave svetlosti na kožu su prekomerno stvaranje reaktogenih vrsta kiseonika, azota i hiperpigmentacija, a indirektno utiče na kožu poremećajem cirkadijalnog ritma i lučenjem melatonina. Plava svetlost ima direktan uticaj na hromofore koje su prisutne u koži i dovodi do njihove aktivacije. Njihovom aktivacijom dolazi do prekomerne proizvodnje reaktivnih vrsta kiseonika i oslobađanja reaktivnih vrsta azota, odnosno azot monoksida (NO), što pokreće melanogenezu i hiperpigmentaciju. Takođe, dolazi do smanjenja vitalnosti ćelija i/ili proliferacije keratinocita i melanocita, zatim povećane sinteze proinflamatornih interleukina i faktora nekroze tumora alfa i izmenjenog metabolizma kolagena. Plava svetlost smanjuje antioksidativnu zaštitu kože izazivajući razgradnju prisutnih karotenoida. Može se koristiti u kliničkoj praksi u prevenciji i tretmanu određenih dermatoza, kao i u tretmanima fotorejuvenacije u estetskoj medicini. Neophodna su dalja istraživanja u ovoj oblasti.

Ključne reči: plava svetlost, koža, prevencija

Uvod

Sunce emituje vidljivu i nevidljivu svetlost. Ultraljubičasto zračenje (UV) (talasna dužina 280-400 nm) je nevidljivo i čini 3-7% sunčevog spektra, ali i pored toga se najviše istražuje njegovo dejstvo na kožu. U okviru ovog dela sunčevog zračenja, razlikuju se ultraljubičasti zraci (engl. *ultraviolet*) A, B i C (1-4). Infracrveni zraci (engl. *infrared*) nisu vidljivi i predstavljaju elektromagnetne talase dužine od 700 nm do 1 mm (1,4). Ovu energiju osećamo kao toplotu. Sa druge strane, vidljiva svetlost (engl. *visible light* - VIS) je elektromagnetno zračenje koje ljudsko oko može da vidi i čija boja (od crvene do ljubičaste) zavisi od talasne dužine zraka (400-700 nm). Ona čini skoro polovinu sunčevog zračenja.

Plava svetlost (engl. *blue light*) je deo vidljive svetlosti čiji su zraci talasnih dužina između 400 i 500 nm. Ova svetlost se naziva i visokoenergetskom vidljivom svetlošću (engl. *high energy visible light* - HEV) jer u celom spektru vidljive svetlosti ima zrake najkraćih talasnih dužina, ali i najveće energije (2). Poslednjih godina istraživanja ukazuju na njen značaj za oksidativni stres i fotostarenje, kao i na druge neželjene efekte za kožu. Istraživanja vezana za plavu svetlost privlače sve veću pažnju zbog dodatnog izlaganja ljudi ovoj svetlosti kroz različite veštačke izvore kao posledica sve češće upotrebe mobilnih telefona, računara, laptopova, televizora, unutrašnjeg osvetljenja, itd. (2-6).

Uočeno je da plava svetlost utiče na cirkadijalni ritam i samim tim indirektno na kožu. Određen napredak u proučavanju bioloških efekata plave svetlosti je postignut, ali kompletan spektar, tačna priroda i mehanizam delovanja su i dalje nepoznati (1-5). Poslednjih decenija menja se učestalost

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REVIEW PAPER

THE INFLUENCE OF BLUE LIGHT FROM NATURAL AND ARTIFICIAL SOURCES ON THE SKIN

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SUMMARY

Blue light includes rays of lower energy in comparison to UV radiation, but it has a greater power of penetrating the dermis, even to a depth of 1mm. The aim of this review article was to analyze the biological effects of natural and artificial blue light on the skin based on the available literature, as well as to propose preventive measures in order to protect the skin from its harmful effects. The latest research has shown that blue light has various direct and indirect effects on the skin. The direct effects of blue light on the skin are the excessive creation of reactive oxygen species, nitrogen and hyperpigmentation, and it indirectly affects the skin by disrupting the circadian rhythm and secreting melatonin. Blue light has a direct effect on chromophores that are present in the skin and leads to their activation. Their activation leads to the excessive production of reactive oxygen species and release of reactive nitrogen species, that is, nitrogen monoxide (NO), which triggers melanogenesis and hyperpigmentation. Also, there comes to the decrease in cell vitality and/or proliferation of keratinocytes and melanocytes, then increased synthesis of pro-inflammatory interleukins and tumor necrosis factor alpha and altered collagen metabolism. Blue light reduces the antioxidative protection of the skin by causing the degradation of present carotenoids. It can be used in clinical practice in the prevention and treatment of certain dermatoses, as well as in photorejuvenation treatments in aesthetic medicine. Further research in this field is necessary.

Key words: blue light, skin, prevention

Introduction

The sun emits visible and invisible light. Ultraviolet radiation (UV) (wavelength 280-400 nm) is invisible and makes up 3-7% of the sun's spectrum, but despite this, its effect on the skin is the most researched. Ultraviolet rays A, B and C are distinguished within this part of the solar radiation (1-4). Infrared rays are not visible and they represent electromagnetic waves with a length of 700 nm to 1 mm (1,4). We feel this energy as heat. On the other hand, visible light (VIS) is electromagnetic radiation that the human eye can see and whose color (from red to violet) depends on the wavelength of the rays (400-700 nm). It makes up almost half of the solar radiation.

Blue light is a part of visible light whose rays have wavelength between 400 and 500 nm. This light is also called high energy visible light (HEVL) because it has rays of the shortest wavelengths, but also of the highest energy in the whole spectrum of visible light (2). In recent years, research has pointed to its importance for oxidative stress and photoaging, as well as other unwanted effects for the skin. The research related to blue light is attracting more and more attention due to the additional exposure of people to this light through various artificial sources as the result of more frequent use of mobile phones, computers, laptops, televisions, indoor lighting, etc. (2-6).

It has been noticed that blue light affects the circadian rhythm and thus indirectly affects the skin. Some progress in the study of the biological effects of blue light has been achieved, but the

i intenzitet izlaganju plavoj svetlosti, zbog čega se nameće pitanje da li trenutne doze kojima je čovek izložen na dnevnom nivou mogu intenzivirati neželjene efekte plave svetlosti na kožu.

Cilj ovog preglednog rada je bio da se na osnovu dostupne literature analiziraju biološki efekti prirodne i veštačke plave svetlosti na kožu, kao i da se predlože preventivne mere za zaštitu kože od njenih štetnih efekata.

Metode

Ovim preglednim radom obuhvaćena su istraživanja dobijena pretraživanjem literature putem *PubMed* baze na osnovu sledećih ključnih reči: „plava svetlost“, i „koža“, ili „veštačka plava svetlost“ i „koža“. Pretraživanjem je obuhvaćen period od deset godina (od 2014. do 2023. godine). Na osnovu pretraživanja literature identifikovano je 766 publikovanih radova. Kriterijumi za izbor literture za uključivanje u pregledni rad su bili: tekstovi koji su ispitivali vezu između kože i plave svetlosti, objavljeni na engleskom jeziku i koji su bili u celosti dostupni. Kriterijumi za isključivanje su bili: tekstovi koji nisi ispitivali vezu između kože i plave svetlosti, tekstovi u kojima su istraživanja sprovođena na životinjama i tekstovi koji nisu bili napisani na engleskom jeziku. Takođe, pretražena je i citirana literatura svakog izabranog rada, a potom su oni koji zadovoljavaju kriterijume uključeni u pregledni rad.

Direktni i indirektni uticaj plave svetlosti na kožu

Do skoro se smatralo da VIS i konkretno plava svetlost, nemaju uticaj na kožu. Međutim, novije studije ukazuju da plava svetlost ima različite direktne i indirektne efekte na kožu (1-4, 6,7). Direktni efekti plave svetlosti na kožu su prekomerno stvaranje reaktogenih vrsta kiseonika, azota i hiperpigmentacija, a indirektni je poremećaj cikardijalnog ritma.

Plava svetlost ima direktan uticaj na melanogenezu (proizvodnja melanina pod kontrolom tirozinaze), dovodi do njenog indukovanja, izaziva hiperpigmentaciju, pojavu melazme i staračkih pega (1,2). U studiji na 22 zdrava humana dobrovoljaca utvrđeno je da plava svetlost dovodi do pojave hiperpigmentacije, koja je tamnija i duže ostaje na koži, nego ona koja nastaje pod uticajem UV zračenja (1,8). Takođe, odmah dolazi do pojave eritema, koji bledi nakon trideset minuta i potpuno nestaje nakon 2 sata. To znači da kao posledica apsorpcije plave svetlosti od strane pigmenta melanina dolazi do oslobađanja toplote koja vodi vazodilataciji krvnih sudova i pojave eritema (8). Međutim pigmentacija izazvana UV zračenjem je u početku sive boje, a nakon 24 sata prelazi u braon boju i nije okružena eritemom ni u jednom trenutku. Izlaganje opsina 3 (OPN3) u melanocitima plavoj svetlosti dovodi do povećanja fluksa kalcijuma i pokretanja signalne kaskadne rekacije koja uključuje kalcijum-zavisno aktiviranje protein-kinaza, fosforilacije transkripcionog faktora povezanog s mikroftalmijom (MITF) i posledično do povećane sinteze ključnih enzima melanogeneze – tirozinaze i dopahrom tautomeraze koji dovode do formiranja proteinskih kompleksa (tirozinaza-dopahrom tautomeraza kompleks) odgovornih za produženu, perzistentnu pigmentaciju (7). Kod osoba sa tamnijom puti (Fitzpatrick tipovi III-VI) nakon izlaganja kože plavoj svetlosti dolazi do formiranja većeg broja pomenutih proteinskih kompleksa koji dovode do produžene aktivnosti tirozinaze (čime se objašnjava perzistentna, dugotrajna hiperpigmentacija), u odnosu na osobe svetlije puti (Fitzpatrick tip I i II) (2,7,9).

Plava svetlost ima direktan uticaj na hromofore (flavini, porfirini, nitrozovani proteini i opsini) koje su prisutne u koži i aktivira ih. Aktivacija pomenutih hromofora dovodi do prekomerne proizvodnje reaktivnih vrsta kiseonika (engl. *reactive oxygen species*, ROS) i oslobađanja reaktivnih vrsta azota, odnosno azot monoksida (NO). Generisane ROS dovode do pokretanja melanogeneze i pojave hiperpigmentacija (10). Pokazano je da ceo spektar plave svetlosti izaziva prekomerno stvaranje ROS u kultivisanim ljudskim keratinocitima i melanocitima, kao i kod humanih dobrovoljaca (1). Glavne hromofore odgovorne za prekomernu sintezu ROS jesu flavini u mitohondrijama (flavin adenin dinukleotid-FAD i flavin mononukleotid-FMN) i porfirin, odnosno hem (10).

Stvoreni ROS izazivaju oksidativna oštećenja u koži, oštećenja DNK, smanjuju ekspresiju gena koji regulišu funkciju mitohondrija, pa čak kod humanih keratinocita kao klastogeni i aneugeni mogu izazvati aberaciju (1,2). Povećana produkcija ROS izazvana plavim svetlom je povezana i sa smanjenom vitalnošću ćelija i/ili proliferacijom keratinocita i melanocita (supresijom ekspresije gena uključenih u proliferaciju), zatim povećanom proinflamator-

complete spectrum, exact nature and mechanism of action are still unknown (1-5). In recent decades, the frequency and intensity of exposure to blue light has changed, which raises the question of whether the current doses to which humans are exposed on a daily basis can intensify the unwanted effects of blue light on the skin.

The aim of this review article was to analyze the biological effects of natural and artificial blue light on the skin based on the available literature, as well as to propose preventive measures to protect the skin from its harmful effects.

Methods

This review article included the research that was obtained by searching the literature through the PubMed database based on the following key words: "blue light" and "skin", or "artificial blue light" and "skin". The search covered the ten-year period (from 2014 to 2023). Based on the literature search, 766 published papers were identified. The inclusion criteria for the selection of literature in this review article were the following: texts that examined the connection between the skin and blue light, published in English with full texts available. The exclusion criteria were the following: texts that did not examine the connection between the skin and blue light, texts in which research was conducted on animals and texts that were not written in English. Also, the literature of each selected paper was searched and cited, and then those texts that met the criteria were included in the review article.

Direct and indirect effects of blue light on the skin

It has been considered until recently that VIS and specifically blue light have no effect on the skin. However, recent studies have pointed that blue light has various direct and indirect effects on the skin (1-4, 6,7). The direct effects of blue light on the skin are the excessive creation of reactive oxygen species, nitrogen and hyperpigmentation, while the indirect effects include the disruption of the circadian rhythm.

Blue light has a direct effect on melanogenesis (melanin production under the control of tyrosinase), leads to its induction, causes hyperpigmentation, the appearance of melasma and age spots (1,2). In the study of 22 healthy human volunteers, it was found that blue light leads to the appearance of hyperpigmentation, which is darker and lasts longer on the skin than that which appears under the influence of UV radiation (1,8). Also, erythema appears immediately, fades after thirty minutes and disappears completely after 2 hours. This means that heat is released as the result of the absorption of blue light by melanin pigment, which leads to the vasodilatation of blood vessels and the appearance of erythema (8). However, the pigmentation caused by UV radiation is grey in the beginning, and after 24 hours it turns brown and is not surrounded by erythema at all. The exposure of opsin 3 (OPN3) in melanocytes to blue light leads to an increase in calcium flux and the initiation of signaling cascade reaction that includes calcium-dependent activation of protein kinase, phosphorylation of microphthalmia-associated transcription factor (MITF), resulting in the increased synthesis of key enzymes of melanogenesis – tyrosinase and dopachrome tautomerase which lead to the formation of protein complexes (tyrosinase-dopachrome tautomerase complex) that are responsible for the prolonged, persistent pigmentation (7). In people with darker skin (Fitzpatrick types III-IV), after exposure of the skin to blue light, a greater number of the above mentioned complexes are formed, which lead to the prolonged activity of tyrosinase (which0 explains the persistent, long-lasting hyperpigmentation), in comparison to people with lighter skin (Fitzpatrick type I and II) (2,7,9).

Blue light has a direct effect on the chromophores (flavins, porphyrins, nitrosated proteins and opsins) present in the skin and activates them. The activation of the mentioned chromophores leads to the excessive production of reactive oxygen species (ROS) and the release of reactive nitrogen species, that is, nitrogen monoxide (NO). Generated ROS lead to the initiation of melanogenesis and the appearance of hyperpigmentation (10). It has been shown that the entire spectrum of blue light causes the excessive production of ROS in cultured human keratinocytes and melanocytes, as well as in human volunteers (1). The main chromophores responsible for the excessive ROS synthesis are flavins in mitochondria (flavin adenine dinucleotide-FAD and flavin mononucleotide-FMN) and porphyrin, that is, heme (10).

The created ROS create oxidative damage in the skin, DNA damage, reduce the expression of genes

nom signalizacijom (povećava se sinteza proinflamatornih interleukina IL-6, IL-8 IL-1α i faktora nekroze tumora alfa, TNFα) i izmenjenim metabolizmom kolagena (smanjena sinteza prokolagena 1, smanjena kontraktilnost kolagenih vlakana) (1). Dodatno, plava svetlost dovodi do povećane ekspresije matriksnih metaloproteinaza (MMP-1 i 9) i njihovog oslobađanja koje dovodi do razgradnje prisutnog kolagena, sprečavanja reparacije prisutnih i sinteze novih kolagenih vlakana (1,2). Generisanju ROS doprinosi i činjenica da plava svetlost smanjuje antioksidativnu zaštitu kože izazivajući razgradnju prisutnih karotenoida (11). Plava svetlost, naročito ona niže talasne dužine (ispod 453 nm), izaziva oksidativni stres u opsegu koji je ekvivalent 25% oksidativnog stresa izazvanog UVA zračenjem (3). Za oksidativni stres su odgovorni fotosenzitivni proteini flavini koji dovode do stvaranja superoksidnog anjona (O_2^-) – glavnog slobodnog radikala u ovom procesu (12). Takođe, dokazano je u *in vitro*, *in vivo* i *ex vivo* studijama da doprinose i fotostarenju kože (2,13).

Međutim, plava svetlost preko uticaja na cirkadijalni ritam i lučenje melatonina, može indirektno uticati i na kožu. Melatonin, hormon koji luči epifiza, je snažan antioksidans, „hvatač" ROS i stimulator ekspresije gena enzima uključenih u antioksidativni potencijal kože. Kroz ovu antioksidativnu aktivnost, melatonin smanjuje negativan uticaj UV zračenja na kožu, sprečava DNK oštećenja i štiti mitohondrije. Melatonin stimuliše zarastanje rana, ima anti-inflamatorni efekat, utiče na proliferaciju keratinocita i rast kose i može inhibirati melanogenezu i apoptozu, zbog čega se smatra jedinjenjem koje umanjuje znake starenja (engl. *anti-aging*). Njegova koncentracija u telu starenjem opada, kao i razlika u lučenju melatonina tokom noći i dana, zbog čega plava svetlost ima mnogo veći uticaj na mlađu populaciju u odnosu na stariju (14).

Pomenuti efekat na cirkadijalni ritam uključuje stimulaciju senzora svetlosti koji se nalaze u retini oka (centralni mehanizam), kao i periferni mehanizam koji podrazumeva direktnu interakciju sa ćelijama kože. Narušavanjem normalnog cirkadijalnog ritma, plava svetlost može negativno uticati na procese obnavljanja kože koji se odvijaju tokom noći (1,15). Brojne studije su pokazale da plava svetlost talasnih dužina između 459 i 484 nm dovodi do stimulacije melanopsina, hromofore iz grupe proteina opsina prisutnih u retini oka koji su odgovorni za prilagođavanje cirkadijalnog ritma tela ciklusu svetlo/mrak, ukazujući na činjenicu da bi plava svetlost iz veštačkih izvora (digitalni/elektronski uređaji) mogla ometati normalni cirkadijalni ritam, pa samim tim imati uticaj i na fiziološke funkcije kože (10,15). Pokazano je da cirkadijalni ritam ima uticaj na pojedine fiziološke procese u koži. Tako su brzina protoka krvi kroz kožu, propustljivost kože za hidrofilna i lipofilna jedinjenja i transepidermalni gubitak vode veći uveče i tokom noći nego tokom dana, dok je temperatura kože i aktivnost sebacealnih žlezda najveća tokom dana, a opada uveče i tokom noći. Takođe, najintenzivnija proliferacija keatinocita vrši se tokom noći, preciznije oko ponoći (15).

Uticaj plave svetlosti iz veštačkih izvora na kožu

Duteil i saradnici su upoređivali intenzitet plave svetlosti koju emituju digitalni monitori sa intenzitetom plave svetlosti koju emituje sunce, a zatim u *in vivo* studiji na 12 humanih dobrovoljaca (Fitzpatrick tipovi III i IV) procenili uticaj veštačke plave svetlosti na pigmentaciju kože. Ispitivana talasna dužina zraka bila je u opsegu one koju inače emituju digitalni uređaji (mobilni telefoni, računari, televizori) – između 420 i 490 nm, sa pikom u intervalu od 440 do 460 nm, u zavisnosti od uređaja. Zaključeno je da sunce emituje 100 do 1000 puta više plave svetlosti od testiranih digitalnih uređaja. Intenzitet svetlosti je najveći za sunce, a zatim za TV, ekran računara, ekran laptopa, a najmanji za mobilni telefon. Dalje, u *in vivo* studiji u kojoj je vršena procena uticaja veštačke svetlosti na pigmentacije na koži, polovina lica ispitnika je bila izložena plavoj svetlosti simulatora ksenonske svetlosti filtriranog da emituje isti spektar kao ekrani uređaja, a druga polovina lica bila je potpuno zaštićena. Izlaganje je trajalo 8 sati dnevno, 5 uzastopnih dana, nakon čega su upoređivane pigmentne promene na obe polovine lica. Autori su zaključili da izlaganje plavoj svetlosti koju emituju digitalni monitori 8 sati dnevno tokom 5 uzastopnih dana ne dovodi do pogoršanja pigmentnih promena ili do pogoršanja melazme (16). *Ceresnie* i sar. su došli do sličnih zaključaka - nema ni *in vitro* ni *in vivo* dokaza koji bi upućivali da izloženost plavoj svetlosti elektronskih uređaja može dovesti do pigmentacije kože, crvenila, žutila ili pogoršanje melazme. Takođe, izloženost plavoj svetlosti elektronskih uređaja nije klasifikovana kao faktor koji

that regulate mitochondrial function, and even in human keratinocytes as clastogenic and aneugenic can cause aberration (1,2). The increased production of ROS caused by blue light is associated with decreased cell vitality and/or proliferation of keratinocytes and melanocytes (suppression of the expression of genes that are involved in the proliferation), then increased pro-inflammatory signaling (increased synthesis of pro-inflammatory interleukins IL-6, IL-8, IL-1α and tumor necrosis factor alpha, TNFα), and altered collagen metabolism (reduced synthesis of procollagen 1, reduced contractility of collagen fibers) (1). In addition, blue light leads to the increased expression of matrix metalloproteinases (MMP-1 and 9) and their release, which leads to the degradation of the present collagen, preventing the repair of the present and the synthesis of new collagen fibers (1,2). The fact that blue light reduces the antioxidative protection of skin causing the degradation of present carotenoids also contributes to the generation of ROS (11). Blue light, especially that of lower wavelengths (below 453 nm), causes oxidative stress in a range equivalent to 25% of the oxidative stress caused by UVA radiation (3). Photosensitive proteins flavins, which lead to the creation of superoxide anion (O2-) as the main free radical in this process, are responsible for oxidative stress (12). It has also been proven in *in vitro*, *in vivo* and *ex vivo* studies that they contribute to skin photoaging (2,13).

However, blue light can indirectly influence the skin by affecting the circadian rhythm and melatonin secretion. Melatonin, a hormone that is secreted by the pineal gland, is a powerful antioxidant, ROS "catcher" and stimulator of gene expression of enzymes involved in the antioxidative potential of the skin. Through this antioxidant activity, melatonin reduces the negative effect of UV radiation on the skin, prevents DNA damage and protects mitochondria. Melatonin stimulates healing of wounds, has an anti-inflammatory effect, affects the proliferation of keratinocytes and hair growth, and can inhibit melanogenesis and apoptosis, and therefore, it is considered to be the compound that reduces the signs of aging. Its concentration in the body decreases with age, as well as the difference in the secretion of melatonin during night and day, which is why blue light has a much greater effect on the younger population in comparison to the elderly (14).

The above mentioned effect on the circadian rhythm includes the stimulation of the light sensors located in the retina of the eye (central mechanism), as well as the peripheral mechanism, which involves direct interaction with skin cells. By disrupting the normal circadian rhythm, blue light can negatively affect skin renewal processes that take place at night (1,15). Numerous studies have shown that blue light with wavelengths between 459 and 484 nm leads to the stimulation of melanopsin, a chromophore from the group of opsin proteins present in the retina of the eye that is responsible for adjusting the circadian rhythm to the cycle light/dark, pointing to the fact that blue light from artificial sources (digital/electronic devices) could disrupt the normal circadian rhythm, and thus have an effect on the physiological functions of the skin (10,15). It has been shown that the circadian rhythm has an influence on certain physiological processes in the skin. Thus, the speed of blood flow through the skin, permeability of the skin for hydrophilic and lipophilic compounds and transepidermal loss of water are higher in the evening and during the night than during the day, while the skin temperature and the activity of the sebaceous glands are highest during the day and decrease in the evening and during the night. Also, the most intensive proliferation of keratinocytes takes place during the night, more precisely around midnight (15).

The effect of blue light from artificial sources on the skin

Duteil and associates compared the intensity of blue light emitted by digital monitors with the intensity of blue light emitted by the sun, and then in in vivo study on 12 human volunteers (Fitzpatrick types III and IV) estimated the impact of artificial blue light on skin pigmentation. The investigated wavelength of rays was in the range of that which is normally emitted by digital devices (mobile phones, computers, televisions) – between 420 and 490 nm, with a peak in the interval from 440 to 460 nm, depending on the device. It was concluded that the sun emits 100 to 1000 times more blue light than the tested digital devices. The light intensity is the highest for the sun, followed by TV, computer screen, laptop screen, while the lowest is for mobile phones. Furthermore, in one in vivo study, in which the impact of artificial light on skin

dovodi do fotostarenja kože (17). Međutim, uticaj ovih uređaja na kožu tokom dužeg vremenskog perioda se još uvek ne zna i ne može se isključiti.

Uticaj plave svetlosti na prirodni ciklus sna

Cirkadijalni ritam ili prirodni ciklus sna se odnosi na endogeni 24-časovni fiziološki, metabolički ritam i ritam ponašanja ljudskog tela i pod značajnim je uticajem plave svetlosti (6,15). Glavni regulator cirkadijalog ritma je hormon melatonin i njegovo lučenje nije isto u toku 24 časa, već je povećano noću, a smanjeno tokom dana. Izlaganje plavoj svetlosti dovodi do akutnog pada nivoa melatonina, kao posledica smanjenja njegove sinteze. Takođe, povećana upotreba digitalnih uređaja poput laptopova i telefona, naročito upotreba do kasno u noć, ometa cirkadijalni ritam tela i utiče na produkciju melatonina, što dovodi do teškoća sa uspavljivanjem i pospanosti tokom dana (6).

Primena plave svetlosti u dermatologiji i estetskoj medicini

Plava svetlost može se koristiti u dermatologiji i estetskoj medicini. U kliničkoj praksi način korišćenja plave svetlosti (njena talasna dužina i intezitet) zavisi od svrhe ili vrste lečenja. Može se koristi kao samostalan tretman (svetlosna terapija, plava LED terapija) ili deo fotodinamske terapije (2,8). U dermatologiji, preciznije fotodermatologiji, pod kontrolisanim uslovima, plava svetlost se koristi u tretmanu psorijaze, blagih do srednje teških akni, aktiničnih keratoza, atopijskog dermatitisa, ali i u okviru fotorejuvenacije u estetskoj medicini (IPL, engl. *intense pulse light therapy*) (1,2,8). Međutim, treba imati u vidu da se za tretmane plavim svetlom koriste uređaji koji emituju svetlost u kratkom vremenskom periodu (najčešće 15-25 minuta) po sesiji i tretmani obično traju nekoliko nedelja (2).

Zaštita kože od dejstva plave svetlosti

Kada su u pitanju kozmetički proizvodi, poslednjih nekoliko godina povećao se broj dostupnih sastojaka za koje se tvrdi da štite kožu od plave svetlosti (18). Kako je plava svetlost deo sunčeve svetlosti, prva linija zaštite jesu organski i neorganski/fizički filteri - sastojci koji pružaju zaštitu kože od sunčevog zračenja. Međutim, svega dva organska filtera imaju širok spektar zaštite i efikasni su protiv plave svetlosti: fenilen bis-difeniltriazin (INCI: *Phenylene Bis-Diphenyltriazine)* i metilen bis-benzotriazolol tetrametilbutilfenol (INCI: *Methylene Bis-Benzotriazolyl Tetramethylbutylphenol*) (14,19). Što se tiče neorganskih/fizičkih filtera, titan dioksid i cink oksid veličine čestica preko 200 nm reflektuju, rasipaju i delom absorbuju vidljivu svetlost i efikasni su u zaštiti kože od plave svetlosti (7,20), ali se dovode u pitanje senzorne karakteristike ovih proizvoda (beli trag na koži) naročito nakon primene kod korisnika tamnije puti. Dalje, oksidi gvožđa – neorganski pigmenti u sastavu proizvoda dekorativne kozmetike (tečni puderi, tonirane kreme), sami ili u kombinaciji sa neorganskim/fizičkim filterima, takođe pružaju zaštitu od plave svetlosti. Dodatnu zaštitu od plave svetlosti pružaju i antioksidansi koji sprečavaju generisanje ROS: biljni ekstrakti (ekstrakt ploda brusnice, zimske trešnje (ašvagande), đumbira, pirinča, nevena, semena kakaa, ploda i semena šargarepe), zatim izolovani biljni karotenoidi (beta karoten, lutein, likopen), niacinamid i pojedine alge (18). Kao novije aktivne supstance koje pružaju zaštitu od plave svetlosti pominju se i one koje imaju aktivnost sličnu melatoninu (engl. *melatonin-like ingredient*), poput ekstrakta ploda gardenije (14).

Ipak, najbolja strategija zaštite bi bila izbegavanje izlaganja sunčevoj svetlosti tokom dana, smanjen uticaj plave svetlosti na cirkadijalni ritam tokom noći, korišćenje kozmetičkih proizvoda za zaštitu kože od sunca sa filterima širokog spektra tokom dana i sa sastojcima koji imaju uticaj na uklanjanje nastalih promena na koži tokom noći (sastojci koji deluju depigmentišuće, podstiču sintezu kolagena i antioksidansi).

Zaključak

Plava svetlost ima različite direktne i indirektne efekete na kožu koji zavise od talasne dužine i intenziteta izlaganja. Plava svetlost se može koristiti u kliničkoj praksi pod kontrolisanim uslovima u prevenciji i tretmanu određenih dermatoza, kao i u tretmanima fotorejuvenacije u estetskoj medicini. Međutim, treba imati u vidu da pored korisnih, plava svetlost iz prirodnih i veštačkih izvora ima i štetne efekte na kožu. Iako je uticaj prirodne plave svetlosti svakako značajniji u odnosu na uticaj svetlosti iz veštačkih izvora, kako će izloženost veštačkoj plavoj svetlosti verovatno nastaviti da raste, potrebna su opsežnija i dugotrajnija ispitivanja u ovoj oblasti.

pigmentation was evaluated, half of the examinee's face was exposed to the blue light of a xenon light simulator, which was filtered to emit the same spectrum as the device's screens, and the other half of the face was completely protected. The exposure lasted 8 hours a day, for 5 consecutive days, after which the pigment changes on both halves of the face were compared. The authors concluded that exposure to blue light emitted by digital monitors 8 hours a day, for 5 consecutive days did not lead to worsening of pigment changes or worsening of melasma (16). Ceresnie and associates came to similar conclusions – there was no *in vitro* and *in vivo* evidence that exposure to blue light from electronic devices can lead to skin pigmentation, redness, yellowing or worsening of melasma. Also, exposure to blue light from electronic devices was not classified as a factor that leads to photoaging of the skin (17). However, the influence of these devices on the skin over a longer period of time has not been known so far and cannot be excluded.

The influence of blue light on the natural sleep cycle

Circadian rhythm or natural sleep cycle refers to the endogenous 24-hour physiological metabolic and behavioral rhythm of the human body and it is significantly influenced by blue light (6,15). The main regulator of the circadian rhythm is the hormone melatonin, and its secretion is not the same during 24 hours, but it increases at night, and decreases during the day. The exposure to blue light leads to an acute decrease in the level of melatonin, as the consequence of its decreased synthesis. Also, the increased use of digital devices, such as laptops and mobile phones, especially late at night, disrupts the circadian rhythm and influences the production of melatonin, which leads to difficulties related to falling asleep and daytime sleepiness (6).

The application of blue light in dermatology and aesthetic medicine

Blue light can be used in dermatology and aesthetic medicine. In clinical practice, the way in which blue light is used (its wavelength and intensity) depends on the purpose or type of treatment. It can be used as an independent treatment (light therapy, blue LED therapy) or as part of photodynamic therapy (2,8). In dermatology, more precisely, in photodermatology, under controlled conditions, blue light is used for the treatment of psoriasis, mild to moderately severe acne, actinic keratoses, atopic dermatitis, as well as in photorejuvenation in aesthetic medicine (intense pulse light therapy, IPL). (1,2,8). However, one should have in mind that devices, which emit light for a short period of time (mostly 15-25 minutes) per session, are used in blue light treatments, and these treatments usually last for several weeks (2).

The protection of the skin from the effects of blue light

When it comes to beauty products, the number of available ingredients, which are claimed to protect the skin from blue light, has increased in the last years (18). Since blue light is part of sunlight, the first line of defense includes organic and inorganic/physical filters – ingredients that protect the skin from solar radiation. However, only two organic filters have a wide range of protection and are effective against blue light: Phenylene Bis-Diphenyltriazine and Methylene Bis-Benzotriazolyl Tetramethylbutylphenol (14,19). As far as inorganic/physical filters are concerned, titanium dioxide and zinc oxide that have particles over 200 nm reflect, scatter and partially absorb visible light and are effective in protecting the skin from blue light (7,20), but the sensory characteristics of these products are questioned (white marks on the skin), especially when they are applied by people with darker skin. Furthermore, iron oxides – inorganic pigments that are ingredients of beauty products (liquid powders, tinted creams), alone or in combination with inorganic/physical filters also have protection against blue light. Additional protection from blue light is also provided by antioxidants that prevent the production of ROS: plant extracts (cranberry extract, winter cherry – ashwagandha, ginger, rice, calendula, cocoa seeds, carrot root extract and its seeds), then isolated plant carotenoids (beta carotene, lutein, lycopene), niacinamide and certain algae (18). Some new active substances that provide the protection from blue light are mentioned, and they are melatonin-like ingredients, such as gardenia fruit extract (14).

However, the best protection strategy would be to avoid exposure to sunlight during the day, and reduce the impact of blue light on the circadian rhythm during the night, to use cosmetic

Konflikt interesa

Autori su izjavili da nema konflikta interesa.

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products with broad-spectrum filters during the day which protect the skin from the sun and which have ingredients that have the effect of removing the changes on the skin during the night (ingredients that have depigmenting effects, stimulate collagen synthesis and antioxidants).

Conclusion

Blue light has a variety of direct and indirect effects on the skin that depend on the wavelength and intensity of exposure. Blue light can be used in clinical practice under controlled conditions in the prevention and treatment of certain dermatoses, as well as in photorejuvenation and treatments in aesthetic medicine. However, it should be kept in mind that despite its useful effects, blue light from natural and artificial sources also has harmful effects on the skin. Although the influence of natural blue light is certainly more important than the influence of light from artificial sources, more extensive and long-term research in this field is needed since the exposure to artificial blue light will probably continue to increase.

Competing interests

The authors declared no competing interests.

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