



Examination of the biological effects of sunlight on the skin: a review

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Abstract

Introduction: Sunlight is essential for all living beings. While certain effects of sunlight are well-established, others require further investigation. Sunlight is composed of electromagnetic spectrum radiation, which can be grouped into three main types: visible, ultraviolet (UV), and infrared (IR). UV radiation is split into three subtypes: UVA, UVB, and UVC, each of which owns unique properties and varying effects on the skin.

Methods: In this review, the main databases, including PubMed, Scopus, and Google Scholar were investigated for studies examining the biological effects of sunlight on the skin by using suitable keywords and specific strategies from 2007 to 2024. All the studies that were not about sunlight and skin were excluded.

Results: The influence of sunlight, particularly UV radiation can lead to a range of biological effects that may be both advantageous and detrimental. Sunlight is closely linked with common skin issues such as sunburn, skin aging, and skin cancer; therefore, the primary objective of this review is to examine the various benefits and drawbacks of sunlight exposure on human skin. The negative impact of solar radiation on the skin is especially evident with prolonged exposure, where UV radiation poses serious health risks, including squamous cell carcinoma, melanoma, and basal cell carcinoma, which are the three most common types of skin cancer.

Conclusion: cancers mainly occur due to DNA damage induced by UV, especially UVB radiation. Furthermore, chronic exposure to UV radiation causes photoaging, which is characterized by the early onset of wrinkles, reduced elasticity, and alterations in skin pigmentation, all of which underscore the enduring effects of sunlight on the skin's texture.

Keywords: Sunlight, Skin, Biological effect

Introduction

Sunlight plays a noteworthy role in human life, and life would be almost unfeasible for humans in its absence. Sunlight, which encompasses UV, visible, and IR light, influences different perspectives of human life.¹ Sunlight is vital for the conversion of 7-dehydrocholesterol in the skin to previtamin D₃, which is then processed to the active form of vitamin D.² Sunlight increases the production of serotonin and endorphins, which can uplift mood and decrease the possibility of seasonal affective disorder.³ Moreover, controlled UV emission is utilized to treat skin disorders like vitiligo, eczema, and psoriasis.⁴ Although sunlight is fundamental for our wellbeing, it can also lead to a variety of adverse effects on the skin.⁵ The foremost unfavorable impacts of sunlight are basically caused by UV radiation.⁶ Short-term and long-term exposure to sunlight can yield varying impacts on the skin.⁷ The prompt results of solar radiation contain erythema, pigmentation, burns, and irritation, and long-lasting exposure to sunlight may cause immunosuppression, premalignant lesions,

photoaging, DNA damage, mutations, and skin cancer.^{8,9} Due to concerns regarding the effects of sunlight on skin health, it is crucial to examine the impact of solar radiation on the skin. Thus, this review aims to provide a comprehensive overview of the biological effects of sunlight on the skin, with a special emphasis on the mechanisms of damage by UV radiation on human skin.

Methodology

The Scopus, Google Scholar, and PubMed databases were studied to find any study investigating the effect of sunlight on human skin. The databases were investigated via the keywords “solar”, “skin”, “sunlight”, “biological effect”, “electromagnetic radiation”, “ultraviolet ray”, “visible light”, “infrared radiation”, and their mixtures. All articles, with these keywords in their titles or abstracts, were selected, and unrelated articles were removed. Articles were excluded if they were not published in English, were outdated, or were duplicates. In addition, papers with titles or abstracts that did not address the purpose of this

review were excluded from the study (Figure, 1). Inclusion criteria included studies in English that examine the effect of sunlight on the skin.

The Spectrum of Sunlight

Overall sunlight consists of approximately 44% visible light (ranging from 400 to 780 nm), 53% IR radiation (spanning from 700 nm to 100 μm), and 3% to 7% UV light.¹⁰ According to the wavelengths, UV is classified into three distinct categories: UVA (320-400 nm), UVB (290-320 nm), and UVC (100-290 nm).¹¹ Earth's atmosphere predominantly absorbs UVC radiation, thereby inhibiting its penetration to the skin. UVB radiation is primarily responsible for directly damaging DNA and is the leading cause of sunburn, while UVA radiation penetrates more deeply into the skin, significantly contributing to photoaging and causing indirect DNA damage.¹² Sunlight serves as the main natural source of visible light. Visible light, especially within the blue light spectrum, has gained attention for its influence on skin pigmentation and oxidative stress.¹³ Infrared radiation, especially in the Near-Infrared (NIR) spectrum, has the ability to penetrate the skin significantly, causing the production of Reactive Oxygen Species (ROS) and thermal damage (Table 1).¹⁴

Sunlight Benefits

The skin acts as a secondary eye for humans. Similar to the eyes, human skin possesses proteins that resemble rod and cone photoreceptors. Human melanocytes and keratinocytes have rhodopsin, which helps melanin production in melanocytes (Figure 2). Moreover, rhodopsin decreases the expression levels of keratin-1 and

keratin-10 mRNA, which are the markers of keratinocyte differentiation.^{15,16} Exposure to small amounts of sunlight, particularly in the morning before it reaches its peak intensity, can have beneficial effects on humans in various ways. The required amount of sunlight differs based on such features as age, diet, health history, skin tone, and geographical place. Generally, experts recommend 5-15 minutes of sun exposure, and up to 30 minutes for individuals with darker skin tones, to maximize benefits while minimizing health risks.¹⁷ The sun's UV rays assist the human body in producing Vitamin D, which is essential for bone health, blood cell formation, and immune function. Additionally, it aids in the absorption and utilization of specific minerals such as calcium and phosphate.¹⁸ Sunlight is essential for regulating the biological clock. Specifically, getting some sunlight in the early morning seems to facilitate nighttime sleep and positively influence both the duration and quality of sleep.¹⁹ Exposure to sunlight aids in eliminating excessive

Table 1. Composition and wavelength spectrum of sunlight

Sunlight composition	Amount	Wavelength	Spectrum
IR radiation	53%	750 nm–100 μm	Near 0.76 - 1 μm Mid 3 - 8 μm far infrared 15 - 1000 μm
Visible light	44%	400 - 780 nm	Red 625-750nm Orange 590-625nm Yellow 565-590nm Green 500-565nm Cyan 485-500nm Blue 450-485nm
UV	3% to 7%	100-400 nm	UVA (320-400 nm) UVB (290-320 nm) UVC (100-290 nm)

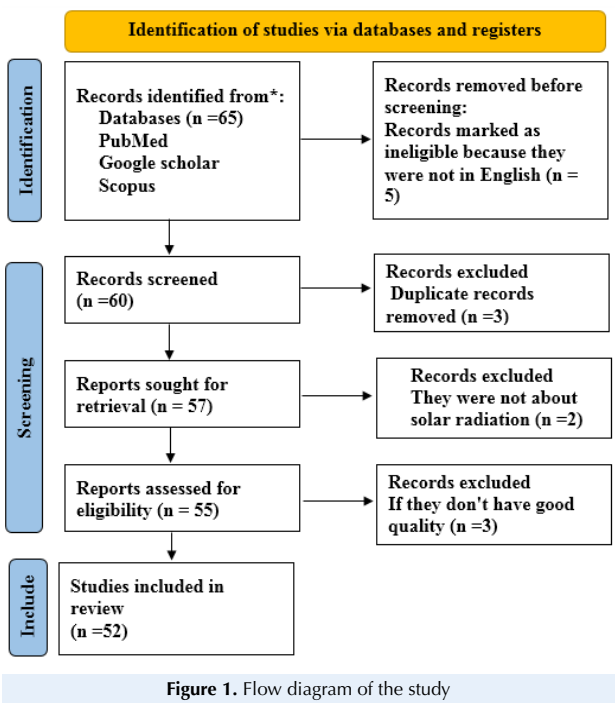


Figure 1. Flow diagram of the study

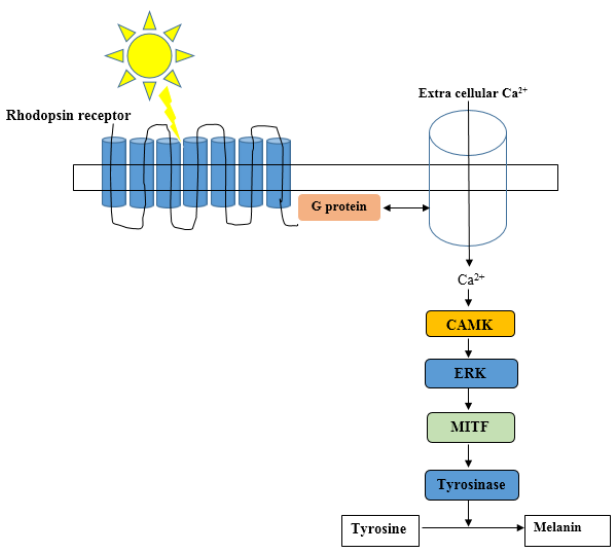


Figure 2. Rhodopsin receptor and signaling pathway in melanocyte. Sunlight activates the rhodopsin receptor and causes the influx of Ca²⁺, which is followed by the stimulation of the CAMK /ERK (Ca calmodulin-dependent protein kinase/ Extracellular signal-regulated kinases) pathway, and it finally results in the phosphorylation of MITF (Melanocyte Inducing Transcription Factor), which increases the melanogenesis enzymes like tyrosinase

body fat. Morning sunlight appears to assist individuals in maintaining weight loss. Regular exposure to the safe amounts of sunlight can help speed up metabolism and might be an effective way to reduce obesity.²⁰ Exposure to sunlight can enhance human mood. Spending 10 to 15 minutes in sunlight daily increases serotonin levels. Furthermore, light has been shown to affect the binding of serotonin at the serotonin 1A receptor site.^{21,22} In addition, sunlight can be used to treat jaundice that frequently affects infants. It occurs when there is too much bilirubin in the blood, which makes a baby's skin appear yellow. Getting sunlight for 30 to 60 minutes twice a day can help bilirubin removal.²³

Harmful Effects of Sunlight

Short-Term Effects

1. Sunburn

Sunburn or erythema is an acute inflammatory response of the skin triggered by exposure to UVB radiation. Sunburn is clinically presented as erythema (redness) of the skin and may result in pain and blister formation. It is an accepted risk factor for the onset of cutaneous melanoma and keratinocyte cancers and may correlate with an elevated risk of herpes zoster.²⁴⁻²⁶

2. Pigmentation

Pigmentation is produced by specialized dendritic cells referred to as melanocytes. These cells synthesize melanin within particular organelles known as melanosomes, which are then conveyed to neighboring keratinocytes. The presence of melanin and the distribution of melanosomes in the epidermis are critical factors in safeguarding the skin against the dangerous effects of UV rays.^{27,28} UVA and UVB rays stimulate pigmentation through different mechanisms. UVA causes immediate darkening of pigment shortly after exposure, as well as delayed tanning that occurs over several days, whereas UVB is responsible solely for delayed tanning.²⁹

Long-Term Effects

1. Photoaging

Prolonged exposure to UVA radiation and UVB radiation leads to photoaging, a condition characterized by the early onset of skin aging.³⁰ This phenomenon is characterized by the development of wrinkles, a decrease in skin elasticity, and alterations in pigmentation, primarily due to the harmful impact of UV rays on collagen and elastin fibers.³¹ Additionally, there is an increase in metalloproteinases (MMPs) within dermal fibroblasts and a buildup of oxidative stress in the skin. Such damage leads to a rough skin texture and uneven pigmentation, both of which are hallmarks of aging.^{32,33} Although treatments like lasers and chemical peels can alleviate some symptoms of photoaging, they are unable to fully reverse the effects of prolonged UV exposure.³⁴

2. DNA damage

UVA and UVB rays both contribute to DNA damage, but UVA is less potent in causing direct DNA damage compared to UVB rays.³⁵ UVA radiation produces ROS, including singlet oxygen and hydroxyl radicals, which have the potential to oxidize DNA bases, leading to mutations like 8-oxoguanine.³⁶ UVB radiation is absorbed directly by DNA, resulting in the creation of thymine dimers. This DNA damage causes distortions in the helical structure, which disrupts both replication and transcription processes.³⁷

3. Immunosuppression

UV radiation contributes to the suppression of both local and systemic immune responses³⁸ by directly or indirectly activating various cells located in the skin. These include epidermal keratinocytes, lymphocytes, Langerhans cells, and mast cells.³⁹ UV radiation alters the activity of cytokines and other immune response mediators, such as platelet-activating factor (PAF), prostaglandin E2, nitric oxide, and antimicrobial peptides.⁴⁰ Some of these mediators facilitate the recruitment of circulating immune cells from the bloodstream. For instance, after exposure to solar radiation, neutrophils quickly infiltrate the skin. These UV-recruited neutrophils and regulatory T cells generate anti-inflammatory and immunosuppressive cytokines such as IL-4, resulting in local immune suppression.^{41,42}

4. Skin cancer

Skin cancer primarily develops due to DNA damage caused by UV radiation that goes unrepaired, along with the effects of immune suppression. Base substitution and pyrimidine dimer formation are among the most important mutations induced by sunlight.^{43, 44} There are three main types of skin cancer: basal cell carcinoma, squamous cell carcinoma, and melanoma.^{45,46} Basal cell carcinoma represents the more common kind of skin cancer, which typically occurs in the body areas that are frequently exposed to sunlight. This form of cancer generally exhibits slow growth and has a low likelihood of metastasis; however, if left untreated, it can lead to the formation of significant sores.^{47,48} Squamous cell carcinoma, while also common, carries a higher risk due to its ability to metastasize, rendering it more perilous than basal cell carcinoma.^{49,50} Although melanoma is the rarest type, it is the most aggressive type of skin cancer and accounts for the majority of fatalities associated with this disease. It is marked by the appearance of new lesions and is closely associated with intermittent ultraviolet exposure and severe sunburn, particularly during childhood and adolescence.^{51,52}

Conclusion

Sunlight has both positive and negative impacts on the skin.

While controlled exposure is needed for the generation of vitamin D and improves psychological health, excessive exposure causes serious concerns like photoaging, DNA harm, and an elevated danger of skin cancer. Due to the diverse impacts of sunlight on skin health, it is critical to conduct research on the biological influences of sunlight on skin health, which was the aim of this study. Future examinations should give enhanced protective strategies and treatments to reduce the long-term consequences of sunlight on the skin.

Authors' Contribution

Conceptualization: Alireza Ahmadzadeh.

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Formal analysis: Zahra Razzaghi.

Investigation: Alireza Ahmadzadeh.

Methodology: Zahra Razzaghi.

Project administration: Alireza Ahmadzadeh.

Resources: Alireza Ahmadzadeh.

Software: Zahra Razzaghi.

Supervision: Alireza Ahmadzadeh.

Validation: Zahra Razzaghi.

Visualization: Zahra Razzaghi.

Writing—original draft: Alireza Ahmadzadeh.

Writing—review & editing: Alireza Ahmadzadeh.

Competing Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

Ethical Approval

This study was approved by IR.SBMU.RETECH.REC.1404.064.

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