The Effect of Ultraviolet Radiation on Human Health

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ABSTRACT

UV radiation has both detrimental effects and medical applications. Overexposure to UV radiation can cause sunburns, premature skin aging, and increase the risk of skin cancer. It can also damage the eyes and weaken the immune system, potentially leading to genetic disorders and various cancers. However, controlled exposure to specific UV wavelengths is used in phototherapy to treat skin disorders like psoriasis, vitiligo, and atopic dermatitis. UV light reduces inflammation and modulates immune responses. UVB radiation enables the synthesis of vitamin D, essential for bone health and immune function. Additionally, UVC radiation has germicidal properties and is used for disinfection in healthcare settings to reduce the risk of infections. To ensure safety, sun protection measures like sunscreen and protective clothing should be followed. In medical settings, UV radiation should be carefully monitored and controlled, and protective measures like UV-blocking goggles and clothing should be used. Regular skin surveillance is important for detecting UV-induced damage. By implementing these measures, the negative effects of UV radiation can be minimized while maximizing its medical benefits

Keywords: UV radiation, skin surveillance, Human Healt

Introduction

Participating Ultraviolet (UV) radiation, a form of electromagnetic radiation emitted by the sun, is a powerful force that plays a significant role in shaping our environment and influencing various biological processes [1]. While moderate exposure to UV radiation is essential for vitamin D synthesis and other vital physiological functions, excessive or prolonged exposure can have detrimental effects on human health [2]. Understanding the impact of UV radiation on human health is crucial for developing preventive measures, promoting public awareness, and developing effective strategies for mitigating potential risks.

The effects of UV radiation on human health are well-documented and encompass a wide range of physiological, cellular, and molecular changes [3]. One of the most well-known and immediate consequences of excessive UV exposure is sunburn, which results in painful inflammation and skin damage. However, the effects of UV radiation extend beyond superficial sunburns and can have long-term implications such as premature aging, wrinkling, and an increased risk of developing skin cancers, including melanoma, the deadliest form of skin cancer [4].

In addition to the skin, UV radiation can impact other organs and systems within the human body. Prolonged exposure to UV radiation can suppress the immune system, making individuals more susceptible to infections and diseases [5]. It can also affect the eyes, leading to conditions such as photokeratitis (inflammation of the cornea) and cataracts (clouding of the lens), which can impair vision [6].

Furthermore, emerging research suggests that UV radiation may have systemic effects on human health, extending beyond the skin and eyes [7]. Studies have indicated potential links between UV radiation and various systemic disorders, including autoimmune diseases, cardiovascular diseases, and certain types of cancer that are not directly related to sun exposure.

Understanding the mechanisms underlying the harmful effects of UV radiation on human health is complex and multifaceted [8]. It involves exploring the interaction between UV radiation and human skin, investigating the cellular and molecular changes that occur upon exposure, and evaluating the role of genetic predispositions and individual susceptibility. Moreover, advancements in technology and changes in environmental factors, such as depletion of the ozone layer, also influence the intensity and impact of UV radiation on human health.

This research study aims to comprehensively examine the effect of UV radiation on human health, encompassing both acute and chronic outcomes [9]. By synthesizing existing knowledge and incorporating new findings, this study seeks to provide valuable insights into the mechanisms, risk factors, and potential preventive measures associated with UV radiation exposure. Ultimately, this research will contribute to the development of evidence-based guidelines, public health interventions, and strategies to minimize the adverse effects of UV radiation and promote overall well-being [10].

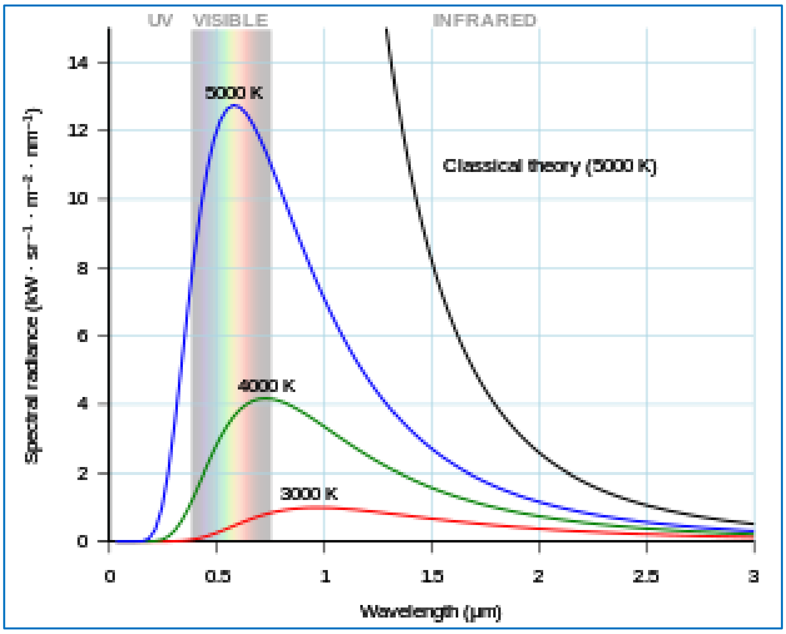
1.2 Literature Review

- **(Hart, Prue H., et al. 2019)** [11] The Montreal Protocol has limited UV-B radiation reaching the Earth due to ozone depletion, yet skin cancer rates continue to rise due to risky sun exposure. Eye disease data is lacking, but UV exposure contributes to cataracts, pterygium, and macular degeneration. UV exposure also affects vitamin D production and immune function, benefiting conditions like psoriasis and multiple sclerosis. Sun protection measures like clothing, sunglasses, shade, and sunscreen mitigate health risks. New sunscreens offer broader protection, but their health benefits are unclear. Knowledge gaps hinder evidence-based sun protection advice that balances the risks and benefits of sun exposure.
- **(Khan, Asfandyar, et al. 2020)** [12] This review examines the impact of ultraviolet (UV) radiation on human health, focusing on the role of textile clothing and chemicals in protecting against its harmful effects. UV radiation is divided into UVA, UVB, and UVC, with UVA being the most prevalent on Earth. Excessive exposure to solar or artificial UV radiation poses significant risks to human health, including the development of various types of skin cancer. The article provides a comprehensive overview of the detrimental effects of UV radiation on the skin, factors influencing UV exposure, and the protective qualities of textile clothing. It also discusses the properties of fibers,

yarns, fabric construction, treatments, and laundering, exploring gaps in existing research. Additionally, a comparison of inorganic and organic UV absorbers and various testing and evaluation methods for UV protective clothing is provided.

- **(Neale, Rachel E., et al. 2021)** [8] The Environmental Effects Assessment Panel (EEAP) of the United Nations Environment Programme (UNEP) presents an updated scientific assessment on the interactions between the stratospheric ozone layer, solar UV radiation, and climate change. The report discusses the impact of these global environmental changes on various aspects, including atmosphere and air quality, human health, ecosystems, biogeochemical cycles, and outdoor materials. The influence of climate change on seasonality and extreme events is highlighted. Furthermore, the assessment explores the transmission and environmental effects of the SARS-CoV-2 virus responsible for the COVID-19 pandemic, considering its connection to solar UV radiation and the Montreal Protocol. This assessment contributes to understanding the complex relationship between ozone depletion, UV radiation, climate change, and their implications for different sectors.
- **(Soundharaj, Sowmiya, M. Ramachandran, and Chinnasami Sivaji. 2022)** [13] Ultraviolet (UV) radiation is a non-ionizing form of radiation emitted by the sun and artificial sources like tanning beds. While it has benefits like vitamin D production, it also poses health risks. UVA and UVB radiation affect human health differently, with UVA penetrating deeper into the skin throughout the year. UVC radiation is absorbed by the ozone layer and poses minimal danger. High-energy UV rays are a type of ionizing radiation that can damage DNA. UVR encompasses wavelengths from 100 to 400 nm, including UVC, which is harmful when generated artificially. Vitamin D is crucial for bone health, and recent research focuses on molecular mechanisms and UV-mediated skin carcinogenesis. Microbial inactivation and wound infection are also areas of study.
- **(Zerefos, Christos, et al. 2023)** [3] Solar ultraviolet-B (UV-B) radiation has been vital for life's evolution on Earth but poses risks and benefits to humans. Determining optimal UV-B exposure behaviors is complex, influenced by environmental and physiological factors. This review examines the current understanding of UV-B radiation's effects on humans and the mechanisms controlling solar UV-B levels at the Earth's surface. It analyzes studies on current trends and future projections of UV-B radiation, highlighting the impact of human-induced climate change. Despite the success of the Montreal Protocol, uncertainties remain regarding future UV-B radiation levels due to climate changes. Precautionary measures to protect against excessive UV-B exposure should continue in the coming decades.
- **(Baldermann, Cornelia, Gudrun Laschewski, and Jens-Uwe Grooß. 2023)** [2] UV radiation is essential for the body's vitamin D production but also a major cause of skin cancer and other health issues. It damages genetic material and is classified as highly carcinogenic. UV-related cancers impose a burden on public welfare and healthcare costs, affecting people of all ages, with children being particularly vulnerable. Scientific knowledge indicates that climate change is altering global and German UV radiation levels, thus impacting the risk of UV-related diseases. Besides individual UV exposure behavior, the presence of UV-protected structures in living environments, such as shaded areas, significantly affects the risk of UV-related diseases.
- **(Guerrero-Navarro, Lena, Pidder Jansen-Dürr, and Maria Cavinato. 2024)** [18] This study investigates the impact of UVA and UVB radiation, in combination with urban particulate matter (UPM), on human dermal fibroblasts (HDF) and skin aging. The research reveals that exposure to UVA/UVB, even at subcytotoxic levels, leads to mitochondrial dysfunction, increased ROS levels, and DNA damage in HDF. These effects can trigger cellular senescence or cell death, depending on autophagy activation. Interestingly, simultaneous UPM treatment with UV-irradiated cells inhibits autophagic flux, shifting cell fate from senescence to apoptotic cell death. The study highlights the synergistic effects of UV radiation and UPM on skin aging and emphasizes the importance of considering environmental stressors in assessing their impact on human health. The findings

suggest the need for comprehensive approaches to protect and preserve skin integrity in the face of increasing environmental challenges.



1.3 Research Aims

1. Investigate the relationship between UV radiation and skin cancer: This research aims to understand how different types of skin cancer are associated with specific wavelengths of UV radiation and their overall impact on cancer development.
2. Assess the effects of UV radiation on skin aging and damage: The goal is to examine how UV radiation accelerates premature aging of the skin, including the formation of wrinkles, sagging, and age spots, by investigating the underlying mechanisms of skin damage caused by UV radiation.

1.4 Research Problem

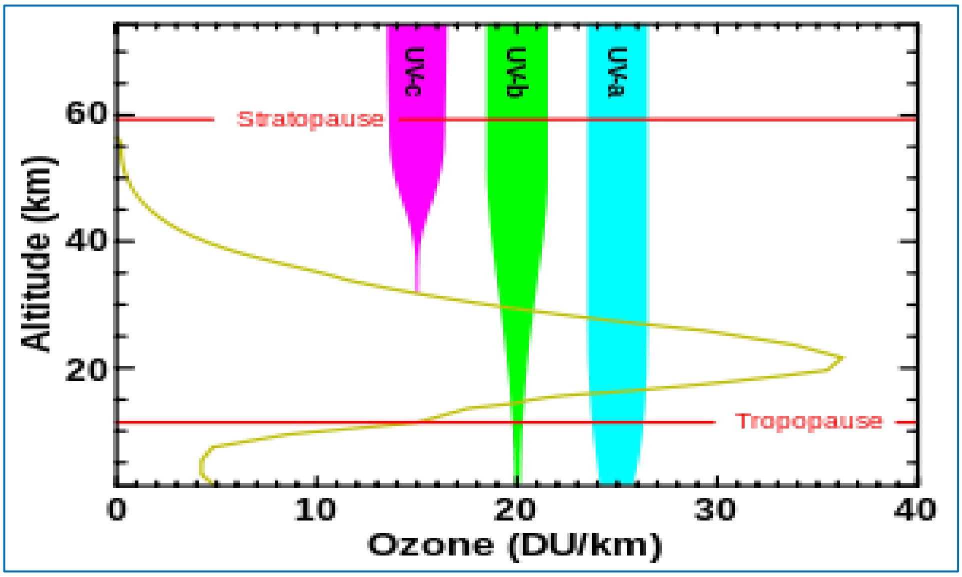
1. Ethical considerations: Conducting research that directly exposes human participants to UV radiation can raise ethical concerns. Exposing individuals to high levels of UV radiation can pose significant risks to their health, potentially leading to sunburn, skin damage, and an increased risk of developing skin cancer. Therefore, researchers must carefully consider the ethical implications and ensure the safety and well-being of study participants.
2. Variability in UV exposure: UV radiation exposure varies greatly depending on geographical location, time of year, weather conditions, and individual behavior. These variations can make it challenging to accurately measure and assess the impact of UV radiation on human health. Researchers must carefully account for these factors and consider the limitations they may impose on the generalizability of their findings.
3. Complex effects and confounding factors: Understanding the specific effects of UV radiation on human health is a complex task. UV radiation can have both beneficial and detrimental effects, and the relationship between UV exposure and health outcomes is influenced by various factors, such as skin type, genetic predisposition, lifestyle choices, and environmental factors.

2.1 Wavelength of Ultraviolet Radiation

Very hot objects emit UV radiation, see black-body radiation in (figure.1). The Sun emits ultraviolet radiation at all wavelengths, including the extreme ultraviolet where it crosses into X-rays at 10 nm. Extremely hot stars (such as O- and B-type) emit proportionally more UV radiation than the Sun. Sunlight in space at the top of Earth's atmosphere is composed of about 50% infrared light, 40% visible light, and 10% ultraviolet light, for a total intensity of about 1400 W/m2 in vacuum [14].

Figure.1: Black-body radiation [14]

The atmosphere blocks about 77% of the Sun's UV, when the Sun is highest in the sky (at zenith), with absorption increasing at shorter UV wavelengths. At ground level with the sun at zenith, sunlight is 44% visible light, 3% ultraviolet, and the remainder infrared. Of the ultraviolet radiation that reaches the Earth's surface, more than 95% is the longer wavelengths of UVA, with the small remainder UVB. Almost no UVC reaches the Earth's surface. The fraction of UVA and UVB which remains in UV radiation after passing through the atmosphere is heavily dependent on cloud cover and atmospheric conditions. On "partly cloudy" days, patches of blue sky showing between clouds are also sources of (scattered) UVA and UVB, which are produced by Rayleigh scattering in the same way as the visible blue light from those parts of the sky. UVB also plays a major role in plant development, as it affects most of the plant hormones [15]. During total overcast, the amount of absorption due to clouds is heavily dependent on the thickness of the clouds and latitude, with no clear measurements correlating specific thickness and absorption of UVA and UVB. The shorter bands of UVC, as well as even more-energetic UV radiation produced by the Sun, are absorbed by oxygen and generate the ozone in the ozone layer when single oxygen atoms produced by UV photolysis of dioxygen react with more dioxygen. The ozone layer is especially important in blocking most UVB and the remaining part of UVC not already blocked by ordinary oxygen in air as



in (figure.2).

Figure. 2: Ozone blocks UVC, most UVB; UVA reaches ground [15]

2.2 Types of Sources of Ultraviolet Radiation

Ultraviolet (UV) radiation can come from various natural and artificial sources. Here are different types of sources of ultraviolet radiation:

1. Sun: The primary natural source of UV radiation is the sun. It emits a wide spectrum of radiation, including UVA, UVB, and a small amount of UVC. UVA radiation makes up the majority of UV radiation reaching the Earth's surface, while UVB radiation is responsible for sunburns and skin damage.
2. Tanning beds and sunlamps: These artificial sources emit UV radiation to simulate the sun's effects for tanning purposes. Both UVA and UVB radiation can be emitted, and the intensity can be significantly higher than natural sun exposure.
3. Welding arcs: Welding processes generate intense UV radiation, primarily UVC and UVB, as a byproduct of the high-energy arc. It is essential for welders to use proper protective equipment to prevent exposure.
4. Germicidal lamps: These lamps are used in various applications, such as water and air purification, medical equipment sterilization, and laboratory settings. Germicidal lamps emit UVC radiation, which has germicidal properties that can kill or inactivate microorganisms.
5. Fluorescent lamps: Standard fluorescent lamps emit a small amount of UV radiation, primarily in the UVA range. However, newer fluorescent lamps with special coatings can reduce UV emissions.
6. Mercury vapor lamps: These lamps are commonly used for outdoor lighting, such as streetlights and sports arenas. They emit a significant amount of UVA and UVB radiation, which can cause skin damage and other health concerns if exposure is prolonged.
7. Phototherapy devices: Certain medical treatments, such as those used for psoriasis, eczema, and other skin conditions, involve the use of UV light devices. These devices emit controlled amounts of UVA or UVB radiation for therapeutic purposes under medical supervision.

2.3 Effect of UV Radiations on Humans

In humans, excessive exposure to UV radiation can result in acute and chronic harmful effects on the eye's dioptric system and retina. The risk is elevated at high altitudes and people living in high latitude areas where snow covers the ground right into early summer and sun positions even at zenith are low, are particularly at risk. Skin, the circadian system, and the immune system can also be affected, figure.3 How UV rays damage skin, eyes and DNA [16].

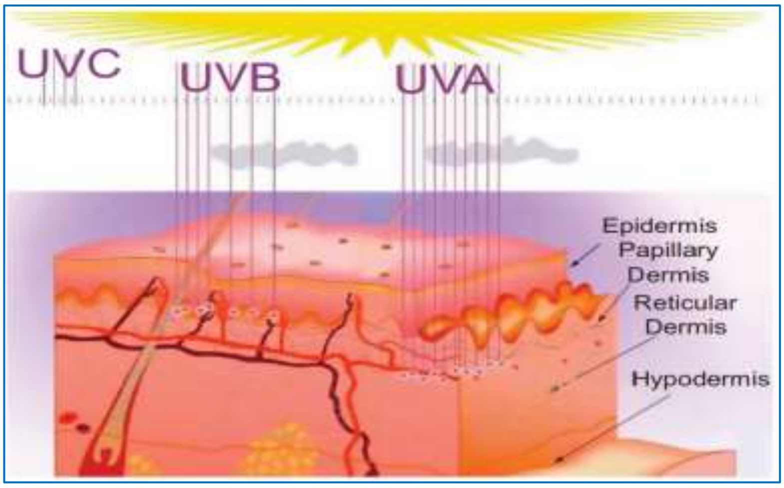
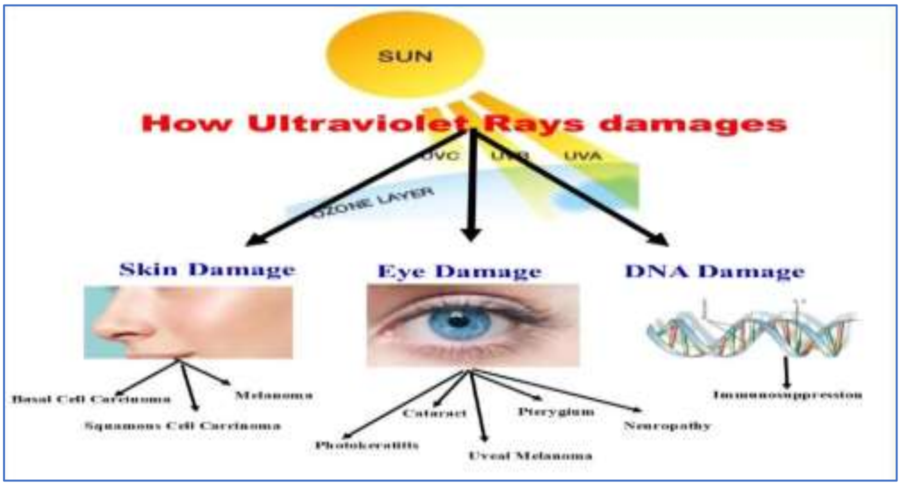


Figure.3: The effect of ultraviolet rays on the body [16]

The differential effects of various wavelengths of light on the human cornea and skin are sometimes called the "erythemal action spectrum". The action spectrum shows that UVA does not cause immediate reaction, but rather UV begins to cause photokeratitis and skin redness (with lighter skinned individuals being more sensitive) at wavelengths starting near the beginning of the UVB band at 315 nm, and rapidly increasing to 300 nm. The skin and eyes are most sensitive to damage by UV at 265–275 nm, which is in the lower UV-C band. At still shorter wavelengths of UV, damage continues to happen, but the overt effects are not as great with so little penetrating the atmosphere. The WHO-standard ultraviolet index is a widely publicized measurement of total strength of UV wavelengths that cause sunburn on human skin, by weighting UV exposure for action spectrum effects at a given time and location. This standard shows that most sunburn happens due to UV at wavelengths near the boundary of the UV-A and UV-B bands [17].



- The human skin can be affected by UVR either through direct or by indirect exposure. With direct interaction, chemical changes in skin cells (DNA) take place, resulting in the formation of new substances such as dimers. Indirect interactions result in the formation of certain reactive species (e.g. singlet oxygen and superoxides etc.) formed as an energy that skin molecules absorb from ultraviolet radiation .UVB and UVC harm the skin by damaging the proteins and nucleic acids while the cause for an underlying effect of UVA is not clear. However, it has been suggested that UVA plays a role in formation of reactive species and genetic activations.

Figure.4: The effect of ultraviolet rays on the skin[17]

- Excessive or prolonged exposure to ultraviolet (UV) radiation can have harmful effects on the eyes [9]. The eye is susceptible to damage from both UVA and UVB rays. Here are some of the harms and effects of UV rays on the eyes:

1. Photokeratitis: This is a painful condition similar to a sunburn of the cornea. It occurs when the eyes are exposed to high levels of UVB radiation, typically from sunlight reflected off snow or water. Symptoms include redness, blurred vision, tearing, and a gritty sensation.
2. Cataracts: Prolonged exposure to UV radiation, particularly UVA and UVB rays, is a risk factor for the development of cataracts. Cataracts cause the lens of the eye to become cloudy, leading to blurred vision and potential blindness if left untreated.
3. Macular degeneration: UV radiation, particularly high-energy blue light, has been implicated in the development and progression of age-related macular degeneration (AMD). AMD affects the central part of the retina, leading to a loss of central vision.
4. Pterygium: UV exposure can contribute to the development of pterygium, a growth of pink, fleshy tissue on the white part of the eye. Pterygium can cause discomfort, redness, and may interfere with vision if it grows large enough to cover the cornea.
5. Cancer: UV radiation exposure is a significant risk factor for skin cancer around the eyelids and on the surface of the eye, such as conjunctival melanoma or basal cell carcinoma. To protect the eyes from harmful UV radiation, it is crucial to wear sunglasses or eyeglasses that block 100% of UVA and UVB rays, as well as a wide-brimmed hat for added protection. Additionally, using UV-blocking contact lenses and seeking shade during peak sun hours can help prevent UV-related eye problems. Regular eye examinations are also important to detect and address any UV-related eye issues promptly [18].

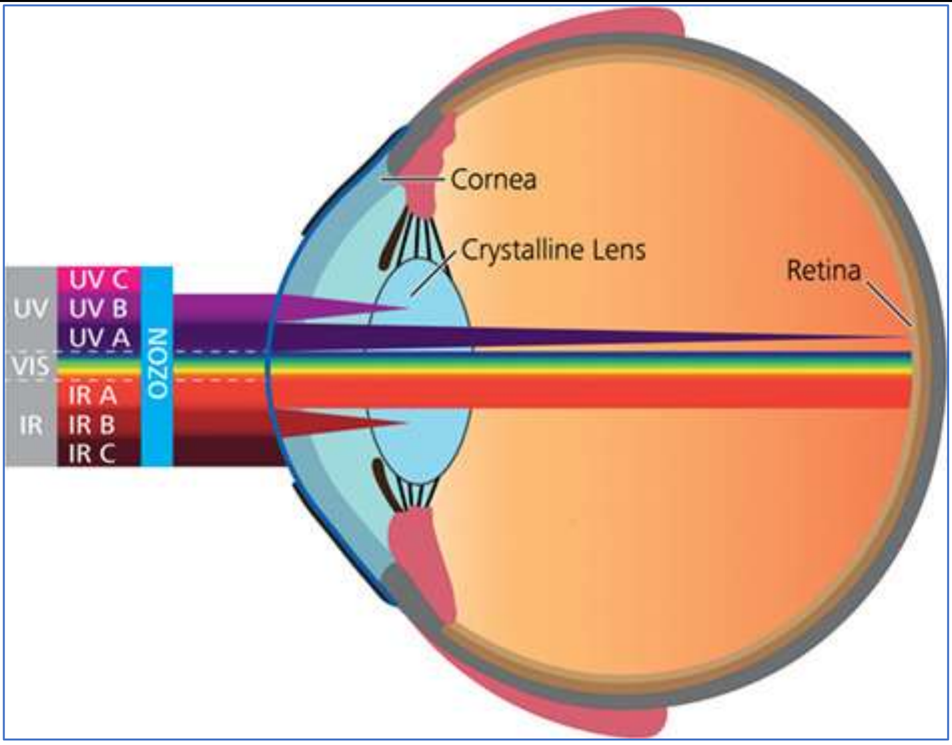


Figure.5: The effect of ultraviolet rays on the eye [18]

- Ultraviolet (UV) radiation can have a significant impact on DNA, the genetic material within our cells. Specifically, UV radiation, particularly UVB and UVC rays, can cause damage to the DNA molecule. Here are some effects of UV radiation on DNA:

1. Formation of DNA Lesions: UV radiation can directly damage DNA by inducing the formation of DNA lesions, such as cyclobutane pyrimidine dimers (CPDs) and 6-4 photoproducts (6-4PPs). These lesions occur when adjacent nucleotides in the DNA strand become chemically bonded together, distorting the DNA structure.
2. DNA Mutations: DNA lesions caused by UV radiation can lead to errors during DNA replication or repair, resulting in permanent mutations in the DNA sequence. Mutations can disrupt the normal functioning of genes and may contribute to the development of diseases, including skin cancer.
3. Activation of DNA Repair Mechanisms: When DNA is damaged by UV radiation, cells activate various DNA repair mechanisms, such as nucleotide excision repair (NER). NER helps to recognize and remove UV-induced DNA lesions, restoring the DNA to its original state.
4. Potential DNA Replication Errors: If UV-induced DNA damage is not repaired before DNA replication occurs, the damaged DNA strand may serve as a template, leading to potential replication errors and the incorporation of incorrect nucleotides into the new DNA strand.

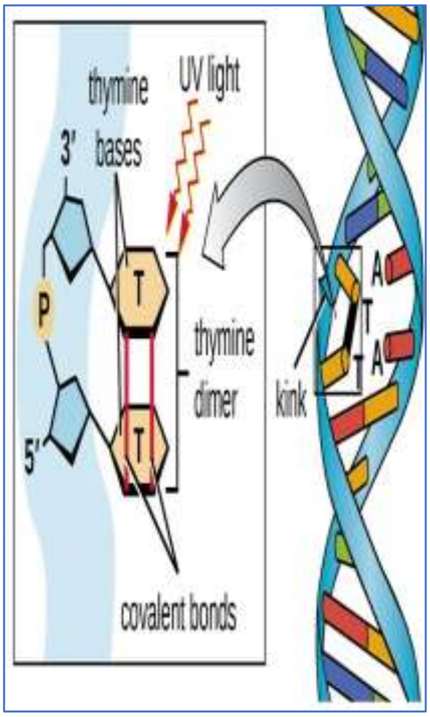


Figure.6: The effect of ultraviolet rays on the DNA [18]

3.1 Medical Phototherapy

Medical phototherapy, specifically involving ultraviolet (UV) radiation, has several important applications in the field of medicine. UV radiation is used in the treatment of skin disorders such as psoriasis, vitiligo, and atopic dermatitis. Phototherapy involves controlled exposure to UV light, which helps to suppress the overactive immune system and reduce inflammation. Narrowband UVB and UVA1 are commonly used in phototherapy, targeting specific wavelengths that are effective in treating these conditions [19]. With proper monitoring and dosage adjustment, medical phototherapy can provide significant relief to patients suffering from various dermatological conditions, improving their quality of life.

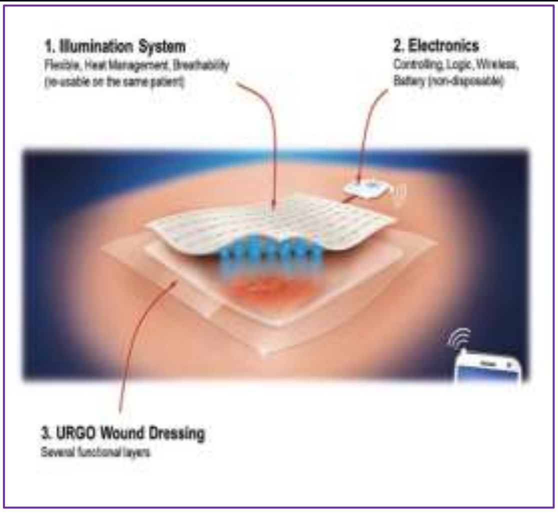


Figure.7: Medical phototherapy, (UV) radiation [19]

3.2 Disinfection

Ultraviolet (UV) radiation has proven to be a valuable tool in the medical field for its disinfection capabilities. UV radiation, particularly in the UVC range (200-280 nm), possesses germicidal properties that can effectively destroy bacteria, viruses, and other pathogens. UV disinfection systems are utilized in healthcare settings to decontaminate surfaces, air, and water, reducing the risk of healthcare-associated infections. These systems are employed in operating rooms, patient rooms, laboratories, and other critical areas. UV disinfection provides a chemical-free and non-toxic method to eliminate harmful microorganisms, contributing to improved infection control and patient safety in healthcare facilities [20].

Figure.8: Disinfection of medical instruments using UV radiation [20]

3.3 Wound Healing

Ultraviolet (UV) radiation has shown potential in wound healing applications. Low-level UV irradiation, particularly in the UVA and UVB ranges, has been studied for its ability to stimulate cellular processes involved in wound repair. UV radiation can promote the production of growth factors, enhance collagen synthesis, increase angiogenesis, and modulate immune responses [21]. These effects can accelerate wound closure, reduce scar formation, and improve tissue regeneration. However, careful dosing and monitoring are crucial to avoid adverse effects such as excessive inflammation or DNA damage. Further research is needed to optimize UV therapy protocols and determine its efficacy in different types of wounds.

Figure.9: Intelligent lighting system for healing wounds using UV radiation [21]

3.4 Vitamin D. Synthesis

Ultraviolet (UV) radiation plays a vital role in the synthesis of vitamin D in the human body. When exposed to UVB radiation from sunlight, a reaction occurs in the skin that converts a precursor molecule into active vitamin D. Vitamin D is essential for maintaining bone health, regulating calcium and phosphorus levels, and supporting immune function. Adequate exposure to UV radiation is necessary for sufficient vitamin D production. However, it is important to balance sun exposure with proper sun protection to minimize the risk of skin damage and skin cancer. In cases of vitamin D deficiency, UV-based phototherapy or vitamin D supplementation may be recommended under medical supervision [22].

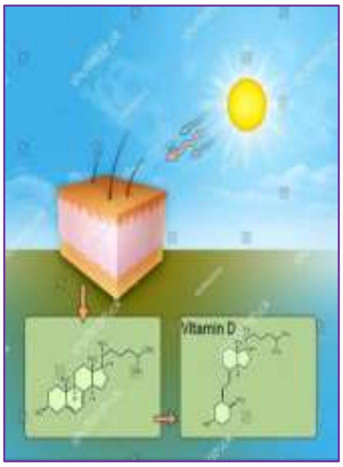


Figure.10: Vitamin D. synthesis by UV radiation [22]

3.5 Medical Safety Measures for the Risks of Exposure to UV radiation

Medical safety measures are crucial to mitigate the risks associated with exposure to ultraviolet (UV) radiation. Here are four key points:

1. Protective Measures: Healthcare professionals and patients should employ appropriate protective measures, such as wearing UV-blocking goggles, gloves, and clothing that cover exposed skin. These measures minimize direct UV exposure and reduce the risk of skin and eye damage.
2. Time and Intensity Control: Medical professionals should carefully monitor the duration and intensity of UV radiation exposure during treatments like phototherapy. Strict adherence to recommended treatment protocols ensures that patients receive optimal therapeutic benefits while minimizing the risk of adverse effects.
3. Regular Skin Surveillance: Patients undergoing UV-based treatments should undergo regular skin surveillance to monitor for any signs of skin damage or abnormalities. Early detection and timely intervention are crucial in managing potential risks associated with UV radiation exposure.

4. Patient Education: It is essential to educate patients about the potential risks of UV radiation exposure, emphasizing the importance of following safety measures and guidelines. Comprehensive patient education promotes awareness, compliance, and responsible self-care, reducing the likelihood of adverse effects and ensuring optimal treatment outcomes.

4.1 Results

UV radiation can have detrimental effects on human health. Overexposure to UV radiation can lead to sunburns, premature skin aging, and an increased risk of skin cancer, including melanoma, basal cell carcinoma, and squamous cell carcinoma. Intense UV exposure can also cause eye damage such as photokeratitis and cataracts. Additionally, prolonged exposure to UV radiation can weaken the immune system and cause DNA damage, potentially leading to genetic disorders and an increased risk of various cancers.

On the other hand, UV radiation have medical applications. Controlled exposure to specific UV wavelengths is utilized in phototherapy for treating skin disorders like psoriasis, vitiligo, and atopic dermatitis. UV light helps reduce inflammation and modulate immune responses. UVB radiation enables the synthesis of vitamin D in the skin, which is essential for bone health and immune function. Furthermore, UVC radiation possesses germicidal properties and is used for disinfection purposes in healthcare settings, reducing the risk of healthcare-associated infections.

To ensure safety, it is important to implement appropriate measures. Sun protection, including sunscreen, protective clothing, hats, and sunglasses, helps minimize UV exposure. In medical settings, time and intensity of UV radiation during treatments must be carefully monitored and controlled. Protective measures such as wearing UV-blocking goggles, gloves, and clothing are essential. Regular skin surveillance is crucial for detecting UV-induced skin damage or abnormalities. By implementing these safety measures, the negative effects of UV radiation can be minimized while maximizing the benefits of medical applications.

4.2 Future Recommendations

1. Investigate long-term effects: Future studies should focus on assessing the long-term impact of UV radiation on human health, including prolonged exposure to sunlight, indoor tanning, and occupational UV exposure. Understanding the cumulative effects of UV radiation can help develop preventive strategies and interventions.
2. Explore genetic susceptibility: Research should examine the role of genetic factors in determining individual susceptibility to UV radiation. Identifying genetic markers associated with increased sensitivity or resilience to UV damage can aid in personalized risk assessments and targeted interventions.
3. Assess emerging technologies: With the advent of new technologies, such as UV-emitting devices for disinfection or therapy, it is vital to investigate their potential health implications. Future studies should evaluate the safety and effectiveness of these emerging technologies, considering both direct and indirect effects on human health.

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