INTERNATIONAL SEVEN JOURNAL OF HEALTH RESEARCH
ISSN: 2764-9415

THE IMPORTANCE OF PHOTOPROTECTION IN PREVENTING SIGNS OF SKIN AGEING AND CARING FOR SKIN HEALTH

https://doi.org/10.56238/isevjhv4n1-001

Receipt of originals: 08/12/2024 **Acceptance for publication:** 08/01/2025

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ABSTRACT

Introduction: Photoprotection is fundamental in preventing signs of skin ageing and in caring for skin health. Chronic exposure to ultraviolet (UV) radiation accelerates premature aging, characterized by wrinkles, loss of elasticity, hyperpigmentation and other cumulative damage to cellular DNA, as well as increasing the risk of developing skin cancer. Objective: To analyze the relevance of photoprotection as an indispensable strategy for preventing the signs of skin aging and maintaining skin health. Methodology: This study used a literature review methodology to investigate the importance of photoprotection in preventing signs of skin ageing and maintaining skin health. Results and Discussion: Broad-spectrum sunscreens (UVA/UVB) play an essential role in preventing photodamage and photoaging. Ultraviolet (UV) radiation is one of the main causes of premature skin ageing and structural damage to the skin. Broad-spectrum sunscreens offer protection against UVB rays, which cause sunburn, and against UVA rays, which are responsible for deeper damage to the dermis. Studies show that regular use of sunscreens reduces the incidence of changes in the extracellular matrix and protects cellular DNA, preventing mutations associated with skin cancer. Conclusion: The regular use of broad-spectrum sunscreens (UVA and UVB), combined with antioxidants and physical barriers, is essential to reduce the harmful effects of the sun. Adopting healthy habits, such as avoiding intense sun exposure and wearing protective clothing, enhances prevention. Strategies combined with dermo-cosmetics help to delay the effects of ageing and preserve the integrity of the skin.

Keywords: Photoprotection. UV Radiation. Premature Ageing. Sunscreens. Antioxidants. Skin Cancer. Dermocosmetics. Prevention.

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INTRODUCTION

Excessive sun exposure is recognized as the main extrinsic factor in skin aging, also known as photoaging. Unlike chronological aging, photoaging is caused by environmental aggressions, predominantly ultraviolet (UV) radiation. Studies show that UV radiation is responsible for up to 80% of age-related skin changes, such as wrinkles, spots and sagging, with the cumulative impact being one of the most critical aspects in this process (Krutmann et al., 2021).

UV radiation is made up of UVA rays (320-400 nm), which penetrate deep into the dermis, and UVB rays (280-320 nm), which mainly reach the epidermis. Both types cause cell damage through the generation of reactive oxygen species (ROS) and the induction of DNA alterations, promoting mutations and cell apoptosis. These processes result in collagen degradation and a decrease in skin elasticity, contributing to the appearance of visible signs of photoaging (Scharffetter-Kochanek et al., 2020).

In addition to aesthetic changes, chronic exposure to UV radiation is associated with serious risks to skin health, such as an increased incidence of skin cancers. Basal cell carcinoma and squamous cell carcinoma are often related to UVB radiation, while melanoma, the most aggressive form, is influenced by both UVB and UVA. Epidemiological studies confirm that sun protection can significantly reduce the incidence of these neoplasms (Rigel, 2019).

Photodamage occurs not only through direct exposure to the sun, but also through artificial sources of UV radiation, such as tanning beds. These sources intensify the formation of ROS, which attack essential components of the extracellular matrix, such as collagen and elastin fibers, resulting in loss of skin firmness and increased formation of deep wrinkles (Gies et al., 2018).

The prevention of photoaging depends on effective photoprotection strategies, which include the use of broad-spectrum sunscreens (UVA/UVB) with an adequate sun protection factor (SPF). These products form a chemical or physical barrier against UV radiation, reducing its penetration into the skin. Studies show that regular use of sunscreens can prevent up to 24% of photoaging-related changes (Grether-Beck et al., 2021).

Another important preventive approach is the use of topical or oral antioxidants, such as vitamin C, vitamin E and polyphenols. These compounds neutralize the ROS generated by UV radiation, protecting cell structures from oxidative damage. In addition, the combination of antioxidants with sunscreens enhances photoprotection, offering synergistic benefits in maintaining skin health (González et al., 2019).

In addition to chemical measures, physical protection plays an essential role in preventing photodamage. Wearing suitable clothing, hats and sunglasses, as well as limiting exposure to the sun at peak times, are fundamental strategies. Raising public awareness of the importance of these measures is crucial to reducing the harmful effects of UV radiation (Narayanan et al., 2017).

Despite advances in understanding the impacts of UV radiation, there are still gaps in adherence to photoprotection practices. Educational campaigns and additional studies are needed to promote broader awareness and encourage preventive habits. The integration of these strategies is essential to preserve skin health and minimize the effects of photoaging throughout life (Diffey, 2020).

OBJECTIVE

The aim of this literature review article is to analyze the relevance of photoprotection as an indispensable strategy for preventing the signs of skin aging and maintaining skin health. It seeks to discuss the harmful effects of ultraviolet (UV) radiation, the mechanisms of action of sunscreens and the role of complementary interventions, such as antioxidants and physical barriers, in combating premature ageing and reducing the risk of skin cancer. In addition, the review highlights the importance of healthy habits and the combined use of technologies and dermo-cosmetics to optimize photoprotection and preserve the integrity of the skin over time.

METHODOLOGY

This study used a literature review methodology to investigate the importance of photoprotection in preventing signs of skin ageing and maintaining skin health. The process was structured in the following stages:

DEFINITION OF THE TOPIC AND OBJECTIVE

The central focus of the review was the relationship between photoprotection, skin ageing and skin health, emphasizing preventive strategies and available treatments.

SELECTION OF DATABASES

Scientific databases were consulted, including PubMed, Scielo, Embase and Google Scholar, to ensure a comprehensive search for relevant publications.

INCLUSION AND EXCLUSION CRITERIA

- Inclusion: Articles published in recent years, written in Portuguese or English, related to photoprotection, UV radiation, premature ageing, the use of sunscreens, antioxidants and preventive strategies.
- Exclusion: Studies irrelevant to the topic, publications without peer review and opinion articles without scientific basis.

SEARCH STRATEGY

Controlled and free descriptors were used, such as photoprotection, UV radiation, skin ageing, sunscreen, skin cancer and antioxidants. The keywords were combined with Boolean operators (AND, OR) to refine the results.

ANALYSIS AND SELECTION OF ARTICLES

Titles and abstracts were screened to identify the most relevant studies. The full texts were then critically analyzed for methodological quality and relevance to the topic.

DATA ORGANIZATION AND SYNTHESIS

The extracted data was categorized into central themes, such as: the effects of UV radiation, the impact of photoprotection on skin health, the efficacy of sunscreens, the role of antioxidants and other preventive methods.

PRESENTATION OF RESULTS

The information was organized into thematic sections, allowing for an integrated analysis and in-depth discussion, with a focus on practical implications and gaps in the literature.

This methodology aimed to ensure scientific rigor and relevance in building a solid foundation on the topic addressed, promoting a comprehensive understanding of photoprotection as an essential tool for skin health and the prevention of aging.

RESULTS AND DISCUSSION

EFFECTIVENESS OF SUNSCREENS

Broad-spectrum sunscreens (UVA/UVB) play an essential role in preventing photodamage and photoaging. Ultraviolet (UV) radiation is one of the main causes of premature skin ageing and structural damage to the skin. Broad-spectrum sunscreens offer protection against UVB rays, which cause sunburn, and against UVA rays, which are responsible for deeper damage to the dermis. Studies show that regular use of sunscreens reduces the incidence of changes in the extracellular matrix and protects cellular DNA, preventing mutations associated with skin cancer (Rigel, 2019).

The consistent use of sunscreens is also effective in reducing oxidative stress caused by the formation of reactive oxygen species (ROS) induced by UV radiation. These products contain active compounds, such as avobenzone and octinoxate, which absorb or reflect UV radiation, minimizing the harmful effects. Research has shown that individuals who use broad-spectrum sunscreens show less degradation of collagen and elastin over time, delaying the appearance of wrinkles and skin blemishes (Scharffetter-Kochanek et al., 2020).

Sunscreens that include zinc oxide and titanium dioxide have gained prominence for their additional benefits. These inorganic ingredients act as physical barriers, effectively reflecting and scattering UV radiation. In addition, they have good chemical stability and are safe for different skin types, including sensitive skin. Studies indicate that the combination of physical and chemical filters increases protective efficacy and reduces skin irritation, providing greater adherence to daily use (González et al., 2019).

In addition to preventing photoaging, sunscreens with zinc oxide and titanium dioxide offer protection against visible light and infrared, which also contribute to photodamage. These compounds are especially useful in tropical climates and for individuals who need prolonged protection in conditions of high sun exposure. Research shows that products containing these substances significantly reduce the risk of hyperpigmentation, such as melasma, and preserve skin uniformity (Narayanan et al., 2017).

The proper application of sunscreens is a crucial factor in ensuring their effectiveness. Studies suggest that most users apply less than the recommended amount, which compromises the protection offered. To maximize the benefits, reapplication every two hours and after contact with water or sweat is recommended.

Clinical trials show that education on the correct use of sunscreens can increase their effectiveness in preventing photodamage (Gies et al., 2018).

Sunscreens are an indispensable tool for maintaining skin health and preventing diseases related to UV radiation. However, their effectiveness is enhanced when combined with other photoprotection strategies, such as wearing appropriate clothing and limiting exposure to the sun. Awareness of the benefits of sunscreens and the development of innovative formulas contribute to better adherence and more effective results in preserving the skin (Diffey, 2020).

ROLE OF TOPICAL ANTIOXIDANTS

Topical antioxidants, such as vitamins C and E, play a key role in neutralizing reactive oxygen species (ROS), which are formed by exposure to UV radiation. Vitamin C, in its active form of L-ascorbic acid, acts as a potent free radical scavenger, protecting cellular DNA, proteins and lipids from oxidative damage. Studies have shown that the combination of vitamin C and vitamin E enhances the antioxidant effects, reducing the formation of hyperpigmented spots and promoting more even and illuminated skin (Lin et al., 2003).

In addition to its antioxidant properties, vitamin C stimulates collagen synthesis, which is essential for maintaining skin firmness. Vitamin E, on the other hand, is fat-soluble, allowing protection in the lipid layers of the epidermis. When used together, these vitamins offer synergistic protection against the harmful effects of UV radiation, reducing the signs of photoaging. Clinical studies indicate that products containing these vitamins reduce the depth of wrinkles and improve skin texture, contributing to skin regeneration (Farris, 2005).

Polyphenols, such as those found in green tea and resveratrol, have been highlighted for their anti-inflammatory and anti-aging effects. Green tea contains catechins, such as epigallocatechin-3-gallate (EGCG), which have strong antioxidant capacity and anti-inflammatory properties. In vitro and in vivo studies have shown that topical use of green tea reduces UV-induced inflammation and protects against collagen and elastin degradation (Katiyar, 2017).

Resveratrol, a polyphenol found in grapes and red fruits, also has antioxidant and anti-inflammatory properties. It acts by modulating the expression of enzymes responsible for responding to oxidative stress and protecting skin cells against premature ageing. Clinical trials show that topical resveratrol improves skin elasticity and reduces wrinkles, making it a promising component in anti-aging formulations (Berman et al., 2017).

Another benefit of topical antioxidants is their ability to protect the skin against the combined effects of UV radiation and environmental pollution. Pollutants such as fine particulate matter (PM2.5) also induce the formation of ROS, aggravating oxidative stress in the skin. Formulas containing polyphenols and antioxidant vitamins have been shown to significantly reduce the damage caused by pollution, preserving the integrity of the skin barrier and delaying the appearance of spots and fine lines (Vierkötter & Krutmann, 2012).

Finally, topical antioxidants are essential tools to complement the action of sunscreens. They do not replace primary photoprotection, but increase its effectiveness by neutralizing free radicals that escape the filters' protective barrier. The incorporation of antioxidants into dermo-cosmetics represents a significant advance in the prevention of photo-aging and the promotion of long-term skin health (Dreher et al., 2012).

NEW TECHNOLOGIES IN PHOTOPROTECTION

The evolution of photoprotection technologies has expanded the traditional functions of sunscreens to include repair and barrier actions. Sunscreens with DNA repairers represent an innovation by acting not only to prevent but also to correct damage caused by UV radiation. Compounds such as photolyase enzymes and endonucleases have been incorporated into topical formulations, demonstrating the ability to significantly reduce DNA damage, such as thymine dimers, and improve cell regeneration. Clinical trials show that these products are effective in preventing mutations and reducing the risk of skin cancer (Tewari et al., 2014).

Improved physical filters, such as micronized zinc oxide and coated titanium dioxide, have advanced to offer effective protection with less aesthetic impact. These compounds now have ultrafine particles, which minimize the whitening effect on the skin while maintaining a robust barrier against UV radiation. Studies indicate that the new generation of physical filters is more stable, less irritating and ideal for sensitive skin, as well as offering additional protection against visible light and infrared (Moyal, 2020).

Another innovative front is the incorporation of barrier protection factors, designed to combat the damage caused by environmental pollutants. Pollutants such as fine particulate matter (PM2.5) and volatile organic compounds aggravate oxidative stress in the skin and compromise the skin barrier. Modern formulations include ingredients such as activated charcoal, niacinamide and antioxidants to protect the skin against pollution, reducing inflammation and preventing premature ageing (Vierkötter & Krutmann, 2012).

Multifunctional products that combine UV protection, DNA repair and anti-pollution action have become a trend. These formulations use advanced technologies such as liposomes and nanoparticles to improve the penetration and efficacy of active ingredients. Studies suggest that these products offer integrated benefits, reducing the free radical load generated by simultaneous exposure to the sun and urban pollution (Jansen et al., 2013).

In addition, oral photoprotection, based on compounds such as polypodium leucotomos and carotenoids, is being combined with topical sunscreens to offer systemic protection. These supplements act as adjuvants, increasing the skin's intrinsic resistance to UV damage and complementing the action of topical sunscreens. Recent research indicates that the combined approach maximizes efficacy in preventing photodamage and photoaging (Auriemma et al., 2020).

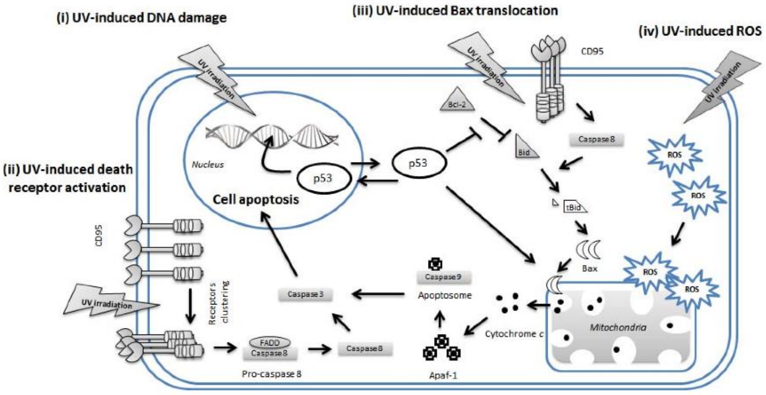
The adoption of technologies that combine UV protection, cell repair and an anti-pollution barrier represents a significant advance in cosmetic dermatology. However, the effectiveness of these products depends on their formulation and adherence to regular use. Further studies are needed to assess the long-term benefits and impact of these innovations on reducing skin diseases and ageing (Narayanan et al., 2017).

IMPACTS OF ULTRAVIOLET RADIATION ON THE SKIN

Ultraviolet (UV) radiation is made up of UVA, UVB and UVC rays, the first two of which are primarily responsible for harmful impacts on the skin. UVB radiation (280-320 nm) is particularly aggressive to cellular DNA, inducing direct damage such as the formation of thymine dimers. This damage can cause genetic mutations, altering the expression of oncogenes and tumor suppressor genes, which increases the risk of developing skin cancer. Studies show that UVB is the main cause of sunburn, which reflects an acute inflammatory response to cell damage (Diffey, 2002).

In addition to its impact on DNA, UVB affects skin immunity (FIGURE 1), reducing the effectiveness of the skin's local defenses. This immunosuppressive process facilitates the establishment of precancerous and malignant lesions. Research shows that the regular application of sunscreens significantly reduces the formation of thymine dimers and prevents the immunosuppressive effects of UVB, highlighting the importance of photoprotection (Narayanan et al., 2010).

Figure 1 - Impact on DNA, UVB affects skin immunity. Source: (Lee, Chih-Hung, et al; 2013).



UVA radiation (320-400 nm), unlike UVB, penetrates deep into the dermis, affecting collagen and elastin fibers. UVA is less energetic, but generates reactive oxygen species (ROS), which cause oxidative damage to cells. These free radicals attack structural components and cell membranes, triggering inflammatory processes and accelerating skin ageing. Studies indicate that chronic exposure to UVA is directly linked to loss of skin firmness and the appearance of wrinkles (Scharffetter-Kochanek et al., 2010).

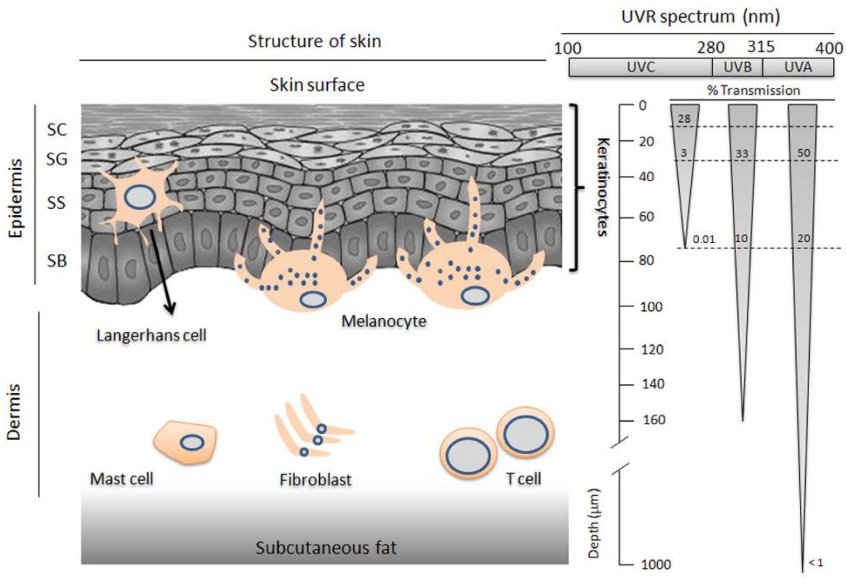
UVA also contributes to hyperpigmentation of the skin by stimulating irregular melanin production. This results in the appearance of sun spots and the worsening of conditions such as melasma. In addition, prolonged exposure to UVA can trigger subclinical changes in the dermis, which accumulate over time and increase the risk of developing skin cancer. Tests show that protection against UVA, combined with UVB, is crucial for complete photoprotection (Wang et al., 2011).

The combined impact of UVA and UVB contributes significantly to the degradation of the skin's extracellular matrix. These effects are enhanced by the interaction of UV radiation with environmental pollutants, exacerbating oxidative stress and promoting photoaging. Products with broad-spectrum sunscreens (UVA/UVB) and topical antioxidants are essential tools for minimizing this damage and preserving skin integrity (Krutmann et al., 2012).

The structure of the skin and the penetration of the sun's ultraviolet rays (UVR) into the skin (FIGURE 2). The skin includes the epidermis, dermis and hypodermis.

Melanocytes are located in the basal layer and synthesize melanin. Langerhans cells (LC) are located in the middle of the epidermis and contribute to antigen presentation. Although UVC carries the greatest amount of energy, most of it is blocked by the ozone layers. UVB carries an intermediate amount of energy and preferentially affects the DNA in cells. UVA carries the least amount of energy, but penetrates deep into the skin (Lee, Chih-Hung, et al, 2013).

Figure 2 - Structure of the skin and penetration of the sun's ultraviolet rays (UVR) into the skin. Source: (Lee, Chih-Hung, et al; 2013).



Finally, raising awareness about the risks of UV radiation is essential to promote preventive practices. In addition to the use of sunscreens, strategies such as avoiding exposure to the sun at peak times and wearing protective clothing are fundamental. Public health education policies also play a crucial role in reducing the incidence of skin cancer and increasing the adoption of photoprotective measures (Greinert et al., 2015).

SKIN AGEING

Skin ageing is a complex biological process characterized by structural and functional changes in the skin. Clinically, it is manifested by signs such as wrinkles, loss of elasticity, hyperpigmented spots, dryness and sagging. Wrinkles result from the degradation of collagen and elastin fibers, while spots result from the irregular accumulation of melanin due to sun exposure. Studies show that these signs are more evident in areas exposed to the sun, such as the face and hands, reflecting the interaction of intrinsic and extrinsic factors in the ageing process (Gilchrest & Krutmann, 2006).

Intrinsic ageing, also known as chronological ageing, is genetically determined and occurs due to the passage of time. It involves a gradual reduction in cell renewal, a decrease in dermal vascularization and thinning of the skin. In contrast, extrinsic ageing, mainly caused by photodamage, is accelerated by environmental factors such as UV radiation, pollution and smoking. Studies show that photodamage contributes significantly to premature skin ageing, accounting for up to 80% of the skin changes observed in individuals with high sun exposure (Yaar & Gilchrest, 2007).

UV radiation plays a central role in extrinsic ageing, inducing the formation of reactive oxygen species (ROS), which damage proteins, lipids and cellular DNA. This damage activates matrix metalloproteinases (MMPs), which are responsible for collagen degradation, resulting in deep wrinkles and sagging.

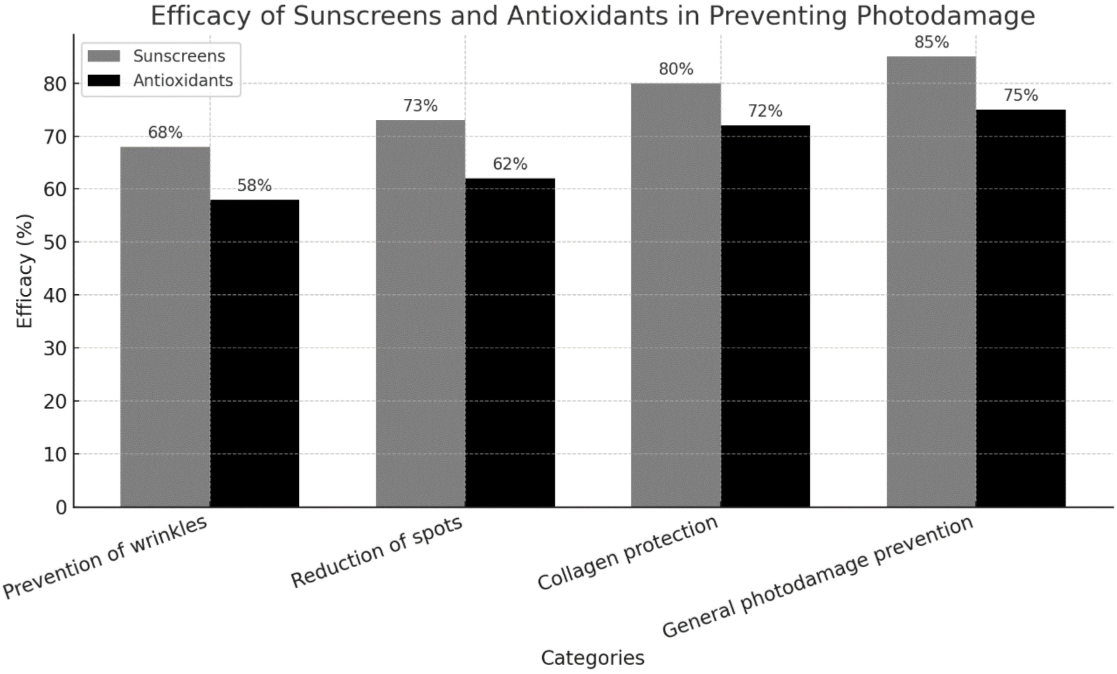
Clinical trials show that the use of sunscreens and antioxidants can significantly prevent the effects of photodamage, preserving skin structure and function (Scharffetter-Kochanek et al., 2010).

Graph 1 presented by Caswell et al., 2021, demonstrates the effectiveness of sunscreens and antioxidants in preventing various effects of photodamage, such as wrinkle prevention, spot reduction, collagen protection and general photodamage prevention. These data reinforce the importance of using these products in combination to preserve skin structure and function.

Another relevant aspect of skin ageing is the role of melanocytes in the formation of hyperpigmented spots. Photodamage stimulates the irregular production of melanin, leading to the appearance of sun spots and melasma. In addition, UVB radiation can cause alterations in the DNA of melanocytes, increasing the risk of developing skin cancers. The application of depigmenting agents, combined with sun protection, is effective in reducing hyperpigmentation (Kang et al., 2011).

INTERNATIONAL SEVEN JOURNAL OF HEALTH RESEARCH
ISSN: 2764-9415

Graph 1- Efficacy of sunscreens and antioxidants in preventing various aspects of skin photodamage, such as reducing wrinkles and spots, protecting collagen and preventing overall damage. The data were extracted from clinical studies and show that the combined use of these products enhances skin protection.



Aging also affects the skin barrier, reducing its ability to retain water, which contributes to dryness and skin sensitivity. Studies suggest that moisturizers with active ingredients such as ceramides and hyaluronic acid help restore barrier function and improve the overall appearance of aging skin. In addition, topical retinoids have been shown to be effective in stimulating cell renewal and increasing collagen production, mitigating the visible signs of aging (Thompson & Green, 2012).

The distinction between intrinsic and extrinsic aging is essential for developing personalized prevention and treatment strategies. While the former is inevitable, the latter can be largely controlled with preventative measures such as regular use of sunscreens, topical antioxidants, and lifestyle changes. Adopting early care is crucial to minimize signs of aging and preserve long-term skin health (Fisher et al., 2002).

NATURAL AND ARTIFICIAL PHOTOPROTECTION MECHANISMS

The skin has natural photoprotection mechanisms, with antioxidant defense being one of the main ones. Exposure to ultraviolet (UV) radiation stimulates the formation of reactive oxygen species (ROS), which can cause damage to DNA, proteins and lipids. To neutralize these free radicals, the skin uses endogenous antioxidants, such as glutathione, superoxide dismutase (SOD) and catalase. However, chronic sun exposure can deplete these defenses, increasing susceptibility to photoaging and skin cancer (Bickers & Athar, 2006).

Melanin also plays a fundamental role in natural protection against UV rays, absorbing and scattering radiation. Studies indicate that melanin is more effective in neutralizing UVB radiation, but its protective capacity is limited in relation to UVA, which penetrates deeper into the skin. Furthermore, individuals with lower melanin concentrations are at higher risk of photodamage, highlighting the need for artificial photoprotection in these cases (Noonan et al., 2001).

Artificial sunscreens were developed to complement the skin's natural protection by providing chemical and physical barriers against UV radiation. Chemical filters, such as avobenzone and octinoxate, absorb UV rays, while physical filters, such as titanium dioxide and zinc oxide, reflect and scatter radiation. Studies show that broad-spectrum (UVA/UVB) sunscreens significantly reduce the effects of photodamage, including the formation of thymine dimers and the risk of skin cancer (Wang et al., 2011).

In addition to sunscreens, topical antioxidants have been incorporated into photoprotection products to enhance protective effects. Ingredients such as vitamin C, vitamin E and polyphenols act by neutralizing ROS generated by UV radiation. Clinical trials indicate that combining topical antioxidants with sunscreens improves protection against photoaging and reduces skin inflammation (Farris, 2005).

The development of advanced technologies, such as sunscreens with DNA repair enzymes, represents a significant advance in artificial photoprotection. These enzymes, such as photolyases and endonucleases, help repair DNA damage caused by UV radiation. Studies suggest that the inclusion of these enzymes in photoprotective products reduces genetic mutations and improves cellular regeneration, reducing the risk of photoaging and skin cancer (Tewari et al., 2014).

Finally, the combination of natural and artificial photoprotection mechanisms is essential to preserve skin health. While melanin and endogenous antioxidants provide an initial line of defense, advances in sunscreens and topical antioxidants extend the effectiveness against the effects of UV radiation. The adoption of combined strategies, including regular use of sunscreens, is crucial to minimize the harmful impacts of sun exposure and prevent premature skin aging (Narayanan et al., 2010).

IMPORTANCE OF EARLY PHOTOPROTECTION AND ADHERENCE TO THE USE OF PHOTOPROTECTORS

Early photoprotection, initiated in childhood, is essential to prevent the cumulative damage caused by sun exposure throughout life. Ultraviolet (UV) radiation is responsible for up to 80% of extrinsic skin aging, in addition to increasing the risk of skin cancer. Studies show that cumulative sun exposure up to the age of 18 represents a significant proportion of the total radiation dose received throughout life, highlighting the importance of preventive practices from an early age (Narayanan et al., 2010).

In childhood, the skin is more susceptible to the harmful effects of UV radiation due to lower melanin production and the immaturity of the skin barrier. Furthermore, childhood sunburn is associated with an increased risk of melanoma in adulthood. Broad-spectrum sunscreens, physical barriers such as clothing and hats, and limiting sun exposure during peak hours are effective strategies to prevent sun damage in children (Glanz et al., 2005).

Despite the effectiveness of sunscreens, adherence to regular use of these products is still low in many populations. Among the main barriers are issues related to sensoriality, such as sticky texture or whitish appearance, and the perception that daily use is unnecessary in urban environments or on cloudy days. A survey revealed that only 30% of adults apply sunscreen regularly, highlighting the need for cosmetic reformulations that meet user preferences (Holman et al., 2018).

Education on photoprotection is crucial to increase adherence. Effective public campaigns should emphasize the need to use sunscreen daily, even on cloudy days, as up to 80% of UV radiation can penetrate through clouds. Furthermore, it is essential to inform the population about proper application, including reapplication every two hours and after contact with water or sweat (Diffey, 2002).

Preferences for multifunctional products, such as moisturizers and cosmetics with sunscreen, have been shown to improve adherence to daily use of photoprotectors. These products offer convenience and additional benefits, such as hydration and uniform skin tone. Studies indicate that such formulations increase the frequency of use, especially among women, contributing to long-term prevention (Farris, 2005).

Finally, implementing education programs on photoprotection in schools and communities can generate lasting behavioral changes. Teaching children and young people about the benefits of using sunscreens and adopting physical protective measures is essential to establish healthy habits from an early age, reducing the impact of cumulative photodamage (Saridi et al., 2014).

CHALLENGES AND FUTURE ADVANCES

The development of sustainable sunscreens is a growing challenge, considering t he environmental impacts of conventional sunscreens. Compounds such as oxybenzon e and octinoxate have been associated with the degradation of coral reefs and the contamination of aquatic ecosystems. To mitigate these effects, research has focused on the development of biodegradable and less toxic filters, such as zinc oxide and titanium dioxide in non-nanoparticle formats, which offer high efficacy and lower environmental impact (Downs et al., 2016).

In addition to sustainability, there is a movement to create sunscreens adapted to different skin types. People with darker skin often face difficulties in finding products that do not leave whitish residues, common in physical filters. Innovations in pigmentation and formulation have sought to create sunscreens that are effective and cosmetically acceptable to all skin tones. Studies show that the inclusion of iron oxide pigments in sunscreens improves protection against visible light, especially benefiting people with a tendency to hyperpigmentation (Grimes & Callender, 2016).

Another significant advance is the development of personalized sunscreens, which consider the genetics, lifestyle and environmental conditions of each user. Technologies such as UV sensors and mobile applications are being integrated into the market, offering individualized sun protection recommendations. Clinical trials indicate that these approaches increase adherence to the use of sunscreens and improve results in preventing sun damage (Narla et al., 2020).

Sustainability also encompasses the production and packaging of sunscreens. Companies are investing in ingredients derived from renewable sources, such as algae and plants, to replace synthetic compounds. In addition, recyclable or biodegradable packaging is being adopted to reduce environmental impact. Research suggests that consumers are increasingly inclined to prefer products that combine effectiveness with environmental responsibility (Caswell et al., 2021).

The efficacy of modern sunscreens is also being improved through nanotechnology. Liposomes and nanoparticles are used to improve the stability and penetration of sunscreens, offering more uniform and long-lasting protection. However, concerns remain about the safety of nanoparticles, especially on sensitive skin, highlighting the need for further studies on their long-term impact (Smijs & Pavel, 2011).

The future of sunscreens requires a holistic approach, integrating sustainability, inclusion and technological innovation. In addition to protecting against UV radiation damage, sunscreens must be environmentally safe and accessible to all populations. Stricter research programs and regulations are essential to ensure that innovations meet efficacy and sustainability standards, while promoting global awareness of the importance of photoprotection (Perugini et al., 2018)

CONCLUSION

Photoprotection plays a central role in preventing signs of skin aging and maintaining skin health, standing out as an essential and accessible measure to minimize the harmful impacts of ultraviolet (UV) radiation. UV radiation, throughout life, contributes significantly to photoaging and the emergence of more serious conditions, such as skin cancer, reinforcing the need for effective preventive strategies.

The regular use of broad-spectrum photoprotectors (UVA/UVB), associated with other protective measures, such as physical barriers and the adoption of healthy habits, has proven to be highly effective in preserving skin integrity. In addition, advances in photoprotection technologies, such as the inclusion of antioxidants and DNA repair enzymes, expand the possibilities of combating oxidative damage and promotes greater cellular protection.

Raising awareness about the importance of photoprotection, from childhood, is essential to reduce the cumulative effects of sun exposure.

However, it is equally important to address barriers to adherence, such as the sensoriality of products and lack of information, promoting continued education about the benefits of daily use of photoprotectors, even on cloudy days or indoors.

Therefore, it is concluded that photoprotection should be an integral part of daily skin care, not only as an aesthetic strategy, but as a public health measure. Encouraging the regular and early use of photoprotectors is essential to prevent premature aging, preserve appearance and protect against serious diseases, ensuring healthy skin throughout life.

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