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Ultraviolet-Protective Clothing and Sunscreen: Sun-Protection for Healthy Skin

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Abstract

Introduction

Prolonged exposure to ultraviolet (UV) radiation from the sun poses numerous risks to the skin, ranging from premature aging to serious health conditions such as skin cancer. UV radiation can penetrate the skin's surface, causing damage to its cells and DNA, which can lead to the formation of wrinkles, sunspots, and other signs of aging. Therefore, consistent and effective sun protection is essential for maintaining the health and vitality of the skin, as well as reducing the risk of sun-related skin damage and diseases.

Aim of the study

The objective of the study is to conduct a thorough investigation into different aspects of photoprotection and its effects on the skin. This entails assessing the effectiveness and safety of sunscreens, as well as evaluating the impact of sun-protection clothing on skin health.

Materials and methods

The purpose of this review is to assess the current literature of the effectiveness of the various sun protection measures. The literature was reviewed in the Pubmed, Google Scholar data base.

Results

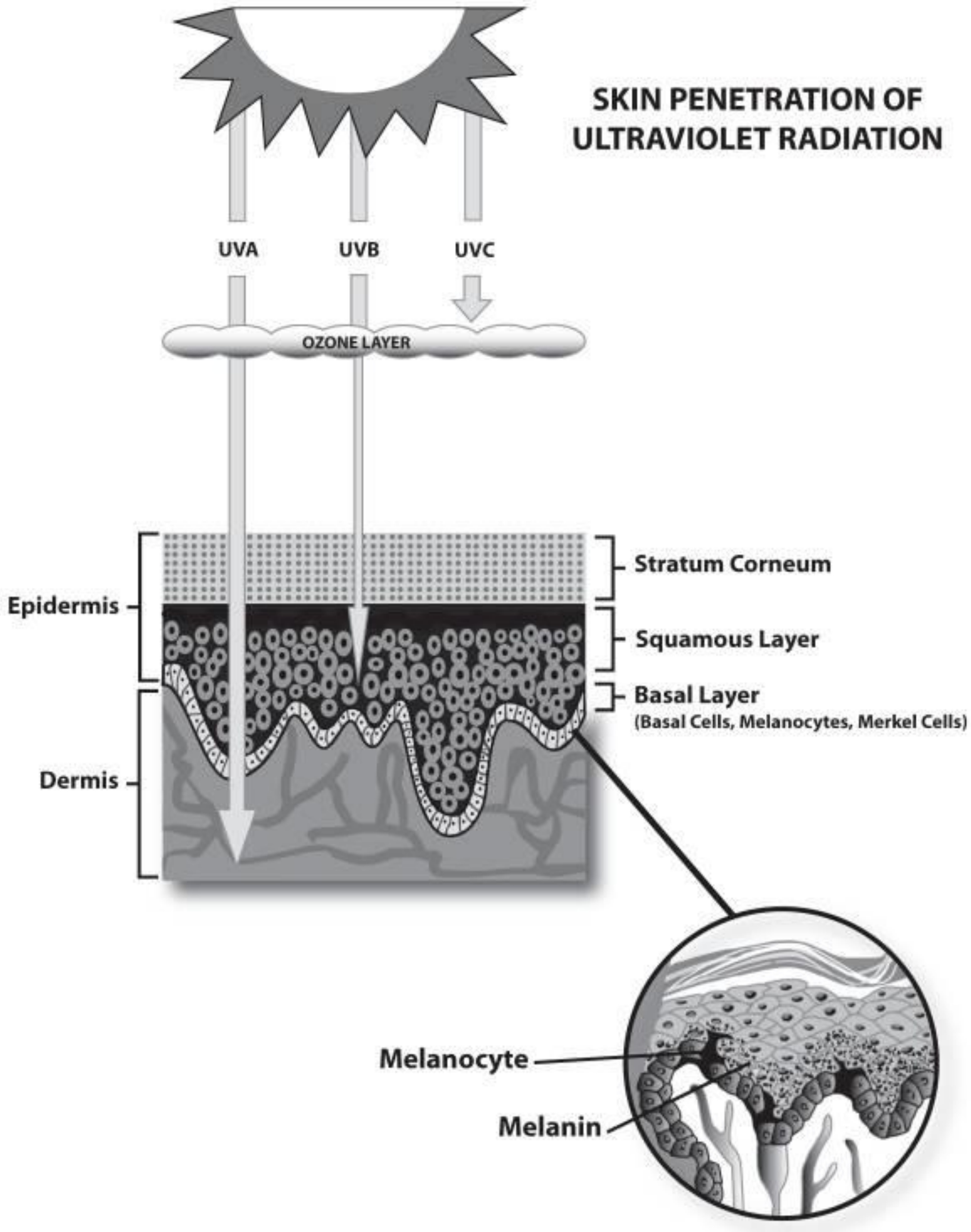
Prolonged UV exposure incites photoaging, carcinogenesis, and immunosuppression, amplifying the risk of skin malignancies. Sun-protective clothing, with adequate UPF ratings, emerges as a pivotal element in mitigating UV-induced skin damage, notably reducing the development of pigmented moles and melanoma. Furthermore, effective sunscreen usage, coupled with broad-spectrum protection, is essential in averting UV-induced skin damage and curbing the incidence of skin cancer. These findings emphasize the imperative of comprehensive photoprotection strategies, integrating sunscreen application, sun-protective clothing, and individual risk assessment, to safeguard against solar-induced skin damage and mitigate the prevalence of skin cancer.
Key words: “UV Protection”; “Sunscreen”, “Photoprotective clothing”.

Introduction and background:

The increase in global temperatures has led to changes in the atmosphere, resulting in a considerable rise in ultraviolet (UV) radiation, mostly emitted by the sun. This has heightened the need for increased awareness and measures to safeguard against sun damage[1]. Long-term exposure to UV radiation causes photoaging, carcinogenesis, and immunosuppression. It ultimately results in skin tumors and involves the manipulation of the immune system as well as the accumulation of genetic alterations[2].

The International Agency for Research on Cancer (IARC) has categorized UV radiation with wavelengths ranging from 100 to 400 nm as harmful to humans. The sun is the primary origin of UV radiation[3]. UV radiation is composed of three parts: UVA, UVB, and UVC. UVC light is absorbed almost entirely by the ozone layer, unlike UVA and UVB rays[4]. However, the ozone layer's loss is causing an increase in the penetration of UVB radiation, which in turn raises the risk of UV-induced carcinogenesis[5]. Ultraviolet (UV) wavelengths induce skin damage through various ways[6].

Figure 1. Types of ultraviolet (UV) radiation and skin penetration[7].



Ultraviolet A (UVA) rays possess the longest wavelength, ranging from 315 to 400 nm. Ultraviolet rays are not absorbed by the ozone layer and can penetrate the skin deeply, reaching the epidermal junction where the melanocytes are located in the basal layer. These rays are mainly responsible for causing premature skin ageing. UVB photons have a shorter wavelength, ranging from 280 to 315 nm. Exposure to both UVA and UVB rays can lead to the development of a tanned complexion. UVB radiation stimulates the formation of melanin, which results in a tan. However, this increased melanin production only provides a modest level of protection against sunlight, approximately comparable to a sun protection factor (SPF) of 3. Additionally, the presence of a tan shows that the skin has been damaged by UVB radiation. It is not believed that tans caused by UVA exposure offer any protection against the harmful effects of sunlight. The majority of UVB radiation is absorbed by the ozone layer, although the quantity can be influenced by climate conditions. Excessive exposure to UVB radiation results in erythema, edoema, and discomfort, which are the typical indications of sunburn and usually manifest after a few hours. UVC rays have the shortest wavelength, ranging from 100 to 280 nm, and are absorbed by the ozone layer and the atmosphere[7].

Preventing skin cancer

Most cases of skin cancer are caused by a combination of risk factors, some of which may be changed (like environmental variables) and others that cannot be changed (like genetic ones). UV radiation exposure is the primary controllable risk factor for skin cancer[8]. Genetic factors have a significant impact on the likelihood of developing skin cancer. The following specific characteristics increase the likelihood of developing skin cancer: Individuals who have a naturally light complexion, light-colored eyes, blonde or red hair, dysplastic nevi or a large number of common moles, and skin that experiences burning, freckling, reddening, or soreness when exposed to excessive sunlight[9].

The sensitivity of the skin to ultraviolet (UV) radiation and the likelihood of getting skin cancer are strongly influenced by the individual's skin tone. The "Fitzpatrick Scale" is a semi-quantitative scale that classifies skin colour into six phototypes based on factors such as basal complexion, melanin level, inflammatory response to UV radiation, and susceptibility to cancer (Table 1). The minimal erythematous dose (MED) is a quantitative method utilised to quantify the amount of ultraviolet (UV) radiation, namely UVB, necessary to induce sunburn on the skin within 24-48 hours following exposure. The determination is made by evaluating the existence of erythema (redness) and edoema (swelling) as markers. UV radiation has a higher tendency to cause inflammation, or sunburn, in those with lighter skin tones. Individuals with dark skin have a higher melanin erythema dose (MED) because their skin contains more eumelanin, which requires a greater amount of UV light to cause sunburn. Conversely, those with fair skin who have a greater amount of pheomelanin typically exhibit lower minimum erythema doses (MEDs). There is a direct relationship between having a low Fitzpatrick phototype and being susceptible to both minimal erythema dose (MED) and other forms of skin cancer, including melanoma[10].

Table1. Skin pigmentation, the Fitzpatrick scale and UV risk [10].

Fitzpatrick phototype	Phenotype	Epidermal eumelanin	Cutaneous response to UV	MED (mJ/cm^2) *	Cancer risk
I	Unexposed skin is bright white Blue/green eyes typical Freckling frequent Northern European/British	+/−	Always burns Peels Never tans	15–30	++++
II	Unexposed skin is white Blue, hazel or brown eyes Red, blonde or brown hair European/Scandinavian	+	Burns easily Peels Tans minimally	25–40	+++/++++
III	Unexposed skin is fair Brown eyes Dark hair Southern or Central European	++	Burns moderately Average tanning ability	30–50	+++
IV	Unexposed skin is light brown Dark eyes Dark hair Mediterranean, Asian or Latino	+++	Burns minimally Tans easily	40–60	++
V	Unexposed skin is brown Dark eyes Dark hair East Indian, Native American, Latino or African	++++	Rarely burns Tans easily and substantially	60–90	+
VI	Unexposed skin is black Dark eyes Dark hair African or Aboriginal ancestry	+++++	Almost never burns Tans readily and profusely	90–150	+/−

Although genetic factors have a substantial impact on the likelihood of getting skin cancer, it is crucial to acknowledge that nearly all instances of skin cancer are also influenced, to varying degrees, by exposure to ultraviolet (UV) radiation. UV radiation stimulates melanocytes to produce melanin, resulting in the development of tanned skin, which acts as an indication of damage to the skin, skin cells, and DNA. Increased levels of exposure can lead to sunburn, which indicates cell death[11].

In a randomized control trial conducted in Australia that was followed up on for over ten years, it was discovered that individuals who were randomly assigned to use daily sunscreen had a 40% reduced risk of squamous cell carcinomas than those who were assigned to use sunscreen

very occasionally. Nevertheless, there was not a significant reduction in the incidence of basal cell carcinomas, potentially as a result of the long-term pathophysiology of these cancers[12].
Melanoma is a cancer that develops in melanocytes, which are cells that produce melanin (pigment) and are located in the basal layer of the epidermis. Melanocytes originate from the neural crest and express many signaling molecules and factors that encourage migration and metastasis following malignant changes. Melanoma, although comprising just 1% of skin malignancies, is responsible for more than 80% of skin cancer deaths.[13]. Incidence rates of melanoma have significantly increased since the mid-1970s. Two main approaches to reduce the risk of melanoma and other skin cancers are avoiding sun exposure and using chemical sunscreens. The incidence and fatality rates of melanoma have been increasing during the 1970s and 1980s, coinciding with the widespread use of high UV protection factor sunscreens[14].

Photoprotection and anti-aging properties

Photo-damaged skin leads to a decrease in skin suppleness, roughness, dryness, uneven pigmentation, and deep wrinkles. Approximately 80% of facial ageing is caused by sun exposure. The most effective way to defend against age-related changes in the skin is through rigorous photoprotection, regardless of the market's focus on reversing skin ageing[15]. Exposure to harmful UV rays causes premature ageing, the production of reactive oxygen species, skin cancer, and breakdown of extracellular matrix components like collagen type I, fibronectin, elastin, and proteoglycans. This is triggered by the increased activity of the mitogen-activated protein kinase signaling pathway[16]. The impact of the UV radiation are significant on a molecular and cellular scale, such as DNA damage, generation of inflammatory mediators, and apoptosis[5] and excessive exposure increases the formation of reactive oxygen species (ROS), which at higher concentrations can damage the main proteins that make up the skin, collagen and elastin[17].
Daily photoprotection and sunscreen use are crucial in preventing photoaging, supported by substantial evidence[18,19]. Furthermore, in a study of 12 subjects in which each subject was exposed to one minimal erythemal dose of simulated solar radiation to three areas of buttock skin (unprotected skin, vehicle, and day cream with UVA and UVB protection) and control (no exposure). The unprotected skin showed notable darkening, thicker outer skin layers, higher levels of tenascin, lower levels of type I procollagen, and slightly increased lysozyme and alpha-1 antitrypsin[20].

Sun-Protective Clothing

According to the limited data available, it is generally agreed that sun-protective clothing is effective in reducing the amount of ultraviolet radiation (UVR) that reaches the skin. The effectiveness of these clothes is measured using the ultraviolet protection factor (UPF) scale or, more recently, the garment protection factor (GPF) scale. The UPF ratings of 15, 30, and 50+ indicate that the corresponding apparel blocks 93.3%, 96.7%, and 98% of ultraviolet radiation (UVR) transmission[21]. In order to obtain the Seal of Recommendation from The Skin Cancer Foundation, the fabric must attain a minimum UPF rating of 30, as determined and demonstrated by the firm applying for the Seal[22]. Nevertheless, the effectiveness of sun-protective apparel has been called into question by numerous external research. In compliance with US regulations, the testing procedure for obtaining the "UV Protective" label necessitates the simulation of two years of usage on the garment before measuring its ultraviolet transmittance. These circumstances involve subjecting the garment to 40 cycles of laundry to simulate the decrease in density that occurs after washing, as well as exposing it to controlled sunshine and/or chlorinated pool water[23].

Non-sun-protective clothing can block UVR to different extents, depending on the particular colour and weave patterns. According to many research findings, colourful garments tend to offer greater UV protection. Garments dyed with deeper colours, such as red, black, or navy blue, consistently exhibit significantly reduced transmission of ultraviolet radiation (UVR) compared to garments dyed with lighter colours, such as pastels, yellow, or white[24].

Although there are several elements that can complicate the process of determining the actual effectiveness of sun-protective apparel, the use of body surface area (BSA) as a measure of UPF through the "hole effect" has been more widely accepted. According to the phenomenon known as the "hole effect," clothing is inherently porous, allowing UVA and UVB rays to be absorbed into the skin at their full intensity[25]. UV textiles have emerged as a promising approach to reduce exposure to ultraviolet radiation (UVR). In order to attain elevated UPF values, photoprotective clothing is purposefully crafted using efficient textile composition and dying patterns, instead of relying on chemical additions. UV textiles are often made of synthetic fibers, specifically polyester and nanofibers. These fibers are closely woven together, resulting in less direct skin exposure to ultraviolet radiation (UVR) due to the "hole effect"[26].

Research has shifted its attention towards studying sun-protective clothing, leading to a growing trend of using the GPF scale instead of the UPF scale to rate the effectiveness of UV-protective clothing. The GPF scale differs from the UPF scale by including both UPF potential and BSA coverage, recognizing the significance of BSA exposure in providing protection against UVR. The GPF scale, which ranges from 0 to 6+, categorizes clothes into three ratings: "minimum" for scores between 0 and 3, "good" for scores between 3 and 6, and "excellent" for scores of 6 or higher. A study conducted by putting sun-protective clothing onto a mannequin and measuring UVR transmittance in relation to both UPF and BSA, discovered that photoprotective clothing may receive a higher UPF rating if it provided sufficient covering of the body surface area (BSA)[27].

UPF clothing's protective characteristics further enhance its anti-carcinogenic capabilities. This study demonstrated that the quantity of pigmented moles is the most prominent risk factor for melanoma. A study was carried out at childcare centers in Australia, and it is the first to demonstrate that it is possible to avoid a significant number of pigmented moles in young Caucasian children by providing them with UPF 30-50+ clothing that covers at least half of their body every day. Wearing such apparel consistently for a period of 3.5 years was determined to be sufficient in preventing approximately 25% of the pigmented moles that are commonly formed on the skin of young children. As a result, this should reduce their likelihood of developing melanoma in the future[28].

Sunscreens

Consumers are finding it challenging to select the appropriate sunscreen due to the variety of options available from cosmeceutical firms, even though there have been slight enhancements in the composition offering various protection, cosmetic, or environmental benefits[29]. Various sunscreens with different SPF levels were evaluated for their effectiveness in preventing UV-induced skin cancer in two types of hairless mice. Albino animals with low protection (SPF = 2) had a 50% reduction in the development of tumors. Strong protection with SPF 15 inhibited the development of tumors. Tumorigenesis was completely inhibited in the lightly pigmented type using sunscreen, highlighting the additional protection provided by melanin. UV-induced cancer is a progressive process in both mice and humans. Limiting UV radiation exposure to the basal layer will slow down that process[30].

Some sunscreens are labelled with a PA+ rating, which stands for "Protection Grade of UVA." The plus signs (PA+, PA++, PA+++, and PA++++) on the product indicate the level of UVA protection offered by the product (or PPD- permanent pigment darkening in the US) which also is denoting their level of protection against UVA rays[31,32]. Typically, sunscreens only shield against UV radiation. A double-beam spectrophotometer was used to visually measure the transmission spectra in order to assess the full solar-spectrum blocking capability of sunscreens from globally recognized firms. Most commercially available sunscreens effectively filter UV radiation but are not effective in blocking visible light and near-infrared radiation. These findings suggest that sunscreens offering broad-spectrum protection from UV to near-infrared radiation should be used to prevent skin damage from sun exposure[33].

Sunscreen products contain a mixture of organic and inorganic filters. Organic filters absorb UV radiation and transform it into benign forms such as heat or light, while inorganic filters decrease UV radiation by reflecting and dispersing it through physical means[34]. Physical sunscreens, including those with zinc oxide and titanium dioxide, provide a barrier that reflects most radiation. They are suitable for youth and sensitive skin because of their minimal allergy risk and great stability in sunlight, but they may leave a glossy or whitish residue, which reduces their aesthetic appeal. The efficacy of these sunscreens is determined on the size and distribution of their particles, where smaller particles offer superior coverage but may lead to more reflection rather than refraction. Chemical filters, or organic filters, absorb UV light and transform it into non-harmful energy radiation. Although effective in avoiding UV damage, organic filters have a higher risk of allergic reactions and worse stability under sunshine when compared to inorganic filters. Advancements have resulted in the creation of novel organic filters that have enhanced photostability and decreased likelihood of allergic reactions, making them safer for long-term usage on the skin. Commercial sunscreens typically utilise a combination of inorganic and organic filters to broaden the range of protection against UVA and UVB rays, take advantage of complementary qualities, and reduce the negative impacts of individual components[35].

The exposome and sun radiation can exacerbate or induce acne. UV light can trigger post-inflammatory hyperpigmentation/erythema and provoke flares[36]. Various guidelines advise the use of photoprotection for those with acne. An expert panel agreed that a comprehensive skin care routine for acne should include using broad-spectrum SPF ≥ 30 sunscreen to decrease photosensitivity caused by topical or systemic treatments[37] and reduced Transepidermal Water Loss[38]. Broad-spectrum sunscreens protect against UV radiation and its harmful effects, while also moisturizing the stratum corneum and improving the skin barrier function. Sunscreens offer protection against pollution and possess sebum-regulating, depigmenting, anti-inflammatory, and antioxidant qualities[39].

Sunscreen safety

A study was done to examine the impact of zinc oxide nanoparticles (ZnO-NP) on human skin following repeated application. The investigation did not detect any ZnO-NP penetration beyond the skin's surface layer or any detrimental alterations to cell structure or function. Zinc species that were made soluble were deposited and mapped in human skin samples outside of the body. This discovery provides clarification to prior research indicating slight yet meaningful elevations in zinc concentrations in the blood and urine of human participants using ZnO-NP. They also stated that the potential risk of skin cancer due to decreased sunscreen use is significantly higher than any potential risk of NP toxicity[40,41].

Benzophenone, which are often included in sunscreens, have been associated with altering hormone activity. Although primarily used for UV protection, they are prevalent in a variety of items and settings, leading to increased exposure[42]. Research indicates that they can penetrate the skin, entering the bloodstream and being discovered in biological fluids such as urine, blood, semen, amniotic fluid, and breast milk. There are concerns regarding how they might affect fetal development and overall health[43]. Yet, the precise health dangers linked to their being in the blood are unclear, emphasizing the necessity for further research on the overall absorption of sunscreen[44].

Certain chemical components in sunscreen can lead to edoema, erythema, and irritation. Some sunscreens contain preservatives, perfumes, and other excipients that may cause adverse reactions in sensitive individuals, potentially reducing patient compliance. Individuals with photodermatitis are prone to developing photo contact dermatitis with sunscreen. Therefore, choosing the right sunscreen is crucial to fully enjoy its benefits[16]. There is no indication of danger from decades of sunscreen use, and no research suggests that any sunscreens on the market should be avoided[45].

Conclusion

In conclusion, preventing skin cancer requires a multifaceted approach that includes regular sunscreen use, adopting sun protection habits, and undergoing regular skin cancer screenings. Prolonged exposure to UV radiation leads to photoaging, carcinogenesis, and immunosuppression, ultimately increasing the risk of skin tumors. UV radiation, particularly UVA and UVB rays, poses significant health risks and contributes to skin damage through various mechanisms. Effective photoprotection is crucial for preventing skin cancer, with UV radiation exposure being the primary controllable risk factor. Genetic factors play a significant role in skin cancer susceptibility, with specific characteristics increasing the likelihood of developing skin cancer.

Sun-protective clothing, with UPF ratings and effective coverage, contributes to anti-carcinogenic abilities and can significantly reduce the risk of pigmented mole development, thereby lowering the risk of melanoma. Sunscreens, with proper SPF levels and broad-spectrum protection, are essential for preventing UV-induced skin damage and reducing the risk of skin cancer.

These conclusions underscore the importance of comprehensive photoprotection measures, including the use of sunscreen, sun-protective clothing, and awareness of individual risk factors, in preventing sun-induced skin damage and reducing the risk of skin cancer.

After conclusions

Author's contribution:

Conceptalization, Daria Sieniawska and Zuzanna Kotowicz, methodology, Patrycja Proszowska, Adrianna Orzeł and Daria Sieniawska, software, Julia Sieniawska, check Magda Madoń and Aleksandra Pich-Czekierda, formal analysis, Zuzanna Kotowicz and Patrycja Proszowska, investigation Adrianna Orzeł and Daria Sieniawska, resources, Julia Sieniawska, data curation, Magda Madoń, writing-rough preparation, Aleksandra Pich-Czekierda, Zuzanna Kotowicz, visualization, Patrycja Proszowska, supervision, Adrianna Orzeł, project administration, Julia Sieniawska, Magda Madoń and Aleksandra Pich-Czekierda

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