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Topical photoprotection in childhood and adolescence

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Abstract

Objective: Exposure to sunlight in childhood is often more intense than in adults. Literature data unequivocally show the association between this social behavior and the risk for developing malignant melanoma and non-melanoma skin cancer, even in adulthood. Furthermore, skin photoaging begins already in childhood through inadequate sun exposure. This review aims to guide pediatricians on appropriate measures of topical photoprotection in children and adolescents, which will positively change the future of these patients.

Sources: A review of the literature indexed in MEDLINE/PubMed between the years 1999 and 2012 on photoprotection in childhood was conducted. The most relevant review articles on photoprotection in children and adolescents, photoprotection and vitamin D in neonatal phototherapy and impact on skin cancer, artificial tanning and skin cancer were selected as sources.

Summary of the findings: Children and adolescents should adopt appropriate measures of photoprotection in order to decrease the risk of melanoma and non-melanoma skin cancer.

Conclusions: There are published data that support the association between sun exposure habits and safe use of topical sunscreens in children and adolescents on the one hand and a reduced occurrence of skin cancer on the other.

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Introduction

The increase in the incidence of skin cancer is due to each individual's behavior regarding sun protection.[1-3] A recent French study showed that 70% of interviewed pediatricians would like to have more information on which photoprotective agents should be indicated to children.[4]

Effective sun protection for children comprises the adoption of several measures, among which adequate clothing and the use of sunscreens.[3,5-8] Sunburns result in skin damage that may cause skin cancer in the future. This lead to the adoption of primary public health measures focused on the prevention of sunburns and the protection from sun exposure.[7,9]

There are several factors that determine sun damage in childhood, its effects and the measures to prevent skin cancer.

Behavioral aspects

The cornerstone of the concept indicating photoprotection in childhood is the knowledge that excessive sun exposure in this age group is a particularly significant factor in the future risk of developing skin cancer.[6]

There are two basic factors that determine a high level of sun exposure in childhood and its relation to skin cancer: (I) unlike most adults in urban environments, children spend a

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great part of their daily time in external environments and, thus, are invariably exposed to the sun; (II) it is known that sunburns in childhood are a fundamental factor in the pathogenesis of malignant melanoma (MM).

Some authors estimate that from 25 to 50% of the sun exposure a person receives during his or her lifetime is obtained before 18-21 years of age.[6,10]

There is a clear relation between sun exposure along the years (cumulative) and the development of skin carcinomas – squamous cell carcinoma (SCC) and basal cell carcinoma (BCC), jointly referred to as nonmelanoma skin cancer (NMSC). There is, furthermore, an acute relation between intermittent sun burn and the development of MM.

Among several measures of protection from solar radiation, the use of topical sunscreens has been shown to prevent the emergence of NMSC.[6] Stern et al.,[11] in the 1980s, showed that the incidence of NMSC throughout life could have a 78% reduction by the use of sunscreens with a sun protection factor (SPF) of 15 or higher during the first 18 years of life.

Another factor that influences an effective sun protection is the age of the child.[12] The age implies the child's capacity of performing photoprotection independently from adults.[12] Conversely, the degree to which children are willing to perform sun protection consistently and by themselves is especially important.[12] In preschool and primary school age children, photoprotection is usually dependent on the degree of the parents' awareness, while in teenagers, personal involvement is determinant for establishing the habit of photoprotection and for this attitude not to be characterized as undesirable for his or her social group.[12] Campaigns to promote sun protection, adequate for each age group, are therefore important.[12]

Another question relevant for children is the use of clothes as a way to perform photoprotection. During the summer of 1990/1991, in Australia, Cancer Council Victoria requested that the protection against ultraviolet radiation (UVR) in T-shirts typically used in the summer in that country would be determined.[13]

There are nowadays in the clothing market clothes that can help in photoprotection. Several features determine if clothes have a good level of photoprotection[13]:

- Cover factor or density of the interlacing: it is defined as the percentage of the fabric surface that is covered by the fiber or thread. The larger the surface covered by the thread or fiber, the smaller the space for UVR passage. Thus, the thinner the interlacing is, the smaller the UVR transmission will be and the greater the fabric's protection.
- Fabric structure: the geometrical disposition of fibers and threads may influence their juxtaposition and is determinant for the fabric's cover factor.
- Weight per area unit: the greater weight of the fabric per area unit also increases the protection factor.
- Fabric thickness: a larger thickness determines an increase of the ultraviolet protection factor (UPF).
- Fabric composition: some materials naturally absorb UVR more intensely than others.
- Color: in general, dark colors and high concentration of dyes absorb more UVR. In the same fabric type, dark colors, such as blue, red and black, absorb more UVR than lighter colors, such as white, light blue or beige.
- Additives added to the fabric: chemicals, such as optical brighteners and UVR reducers, may be added to the fabrics to increase protection.
- Fabric tension: when the fabric is stretched, its UPF might be reduced.
- Fabric humidity: Many clothes, when humid, might have their UPF reduced, depending on the type of fabric and the quantity of humidity absorbed by it.
- Clothing design: depending on the skin exposure in cleavages or sleeves, protection is directly smaller.
- Washing conditions: as they are washed, many clothes shrink, reducing the spaces in the fabric's interlacing and increasing its UPF.

According to these standards, the term UPF designates the amount of protection offered by the fabrics and clothes in addition to the SPF. Table 1 shows the classification scheme for clothes according to the Australian/New Zealand Standards (AS/NZS) 4388 norm. Later, North American, British and European agencies established their own determinations on this issue.[13]

Aspects related to skin color

Skin color has a great influence in the capacity of UVR-induced erythema occurring. In dermatology, the best classification for the capacity of responding with erythema and tanning is Fitzpatrick's, which classifies individuals according to their phototype[14] (Table 2).

The lower incidence of skin cancer among black people results from the photoprotection offered by their abundant epidermal melanin, which provides a natural SPF of about 13.4 in black individuals.[15,16]

Erythema and sunburn

Erythema and sunburn are acute reactions due to excessive exposure to UVR (Figure 1).[14] The minimal erythema dose (MED) refers to the smallest UVR amount capable to induce skin erythema or a light reddening of the skin.[14] MED is dependent on factors such as[14]: (I) Fitzpatrick phototype; (II) skin thickness; (III) amount of epidermal melanin; (IV) production of melanin after sun exposure; and (V) radiation intensity. UVR's capacity to induce erythema

Table 1 - UPF classification scheme according to the Australian and New Zealand AS/NZS 4399 (1966) norm in relation to clothing with sun protection

Protection category	UPF variation	Classification
Excellent protection	40-50, 50+	40, 45, 50, 50+
Very good protection	25-39	25, 30, 35
Good protection	15-24	15, 20

Adapted from Gies.[13]
UPF = ultraviolet protection factor provided by the fabric or clothing.

Table 2 - Fitzpatrick's classification of skin types in relation to sun reactivity

Skin types	Characteristic
Type I	Very light skinned Caucasians who burn very easily and never tan.
Type II	Very light skinned Caucasians who burn very easily and tan slowly and with difficulty.
Type III	Slightly brown skinned Caucasians who burn rarely and tan relatively easily (light brown color).
Type IV	Slightly dark skinned Caucasians that virtually never burn or burn slightly and that tan quickly (moderate brown color). Some individuals with Mediterranean origin or ancestors.
Type V	Asian or Hindu. Rarely burn, tan profusely (dark brown skin).
Type VI	African-Caribbean or blacks. Never burn and are intensely pigmented.

is dependent on the radiation wavelength, which is mainly ultraviolet B (UVB).[14]

Tanning

Tanning is a protective response to sun exposure.[14] Immediate tanning results from the oxidation of melanin prefabricated in the skin after exposure to visible light and to ultraviolet A (UVA)[14]; it is visible after several minutes and disappears in 1 to 2 hours.[14] Late tanning occurs when new melanin is synthesized after UVB exposure, becoming visible after 2 to 3 days of sun exposure, with a peak from 7 to 10 days. It might persist for weeks or months.[14] Thus, sun tanning indicates damage to skin DNA.[14,17]

Sun exposure in childhood

Childhood and adolescence are considered to be critical periods of vulnerability to the effects of exposure to toxic agents.[14] About 25% of the sun exposure in an individual's life occurs before 18 years of age.[14] Exposure to UVR may result in alterations of the melanocytes DNA and in increased risk of carcinogenesis in melanocytic nevi in childhood.[14]

There is a dose-dependent relation between sunlight exposure and the incidence of skin cancer.[15] For the development of melanoma and BCC, intense and intermittent exposure seem to cause a higher risk than chronic smaller exposure, even if the total UVR dose is the same.[15] The risk for SCC, however, is strongly associated to chronic exposure to UVR, but not to intermittent exposure.[15]

In the pediatric age group, as in other age groups, photoprotection must be performed daily. Care related to sun protection must be adopted not only by the use of photoprotectors but also by measures such as an adequate use of clothes and hats, avoiding an exaggerate sun exposure, especially in the times of the day with a higher UVR rate. People should be made aware that, by itself, the use of photoprotector is not an assurance of the necessary protection to prevent skin cancer.

Melanocytic nevi in childhood and sun exposure

The term "melanocytic nevus" means "circumscribed benign hyperplasia of melanocytes in the skin."[18] The common nevi are present in every people. Its kinetics of

Figure 1 - Sunburn with blistering in children: an example of susceptibility to skin cancer in the coming years

appearance on the skin is fast and continues in childhood, from ages 3 to 15, getting in adulthood to an average of 20 to 30 melanocytic nevi in the whole skin.[18] Boys and girls have the same number of nevi but their allotment varies: boys have more nevi in the torso, while girls have more in the limbs.[18]

The atypical or dysplastic melanocytic nevus (Clark nevus) emerges during puberty and its prevalence is from 5 to 10% in the population in general.[18] They are clinically defined by the presence of hair minus three criteria: irregular shape, asymmetry, heterogeneous pigmentation and rosy color at the periphery with a diameter larger than 5mm.[18] The number of nevi increases with age, occurring particularly more in body areas exposed to the sun.

The presence of common melanocytic nevi and atypical nevi is a predictor of risk for melanoma.[18]

The presence of congenital melanocytic nevus (CMN) increases the risk for melanoma.[14] However, the risk for melanoma is directly dependent on the size of CMN and is higher for gigantic nevi (defines as nevi situated on the torso, with over 20 cm in the larger diameter or that one can expect to reach this diameter in adult life).[14] The age average by the time melanoma is diagnosed is around 15.5 years.[14]

The risk for developing malignant melanoma in adulthood is seven times higher in a person who has 100 common melanocytic nevi than in those who present just 15 nevi.[18]

Melanocytic nevi in childhood and phototherapy in the neonatal period

Neonatal jaundice is the most frequent disorder in newborns.[19] Phototherapy during the neonatal period has been recommended since 1958 for the treatment of some degrees of jaundice and the prevention of some more serious complications such as kernicterus. It is doubtless the most used therapeutic modality for the treatment of neonatal hyperbilirubinemia. Estimates show that in the United States alone over 350,000 babies receive this treatment per year.[20]

The principle of phototherapy is the photochemical conversion of bilirubin in areas exposed to light. This reaction changes the structure of the bilirubin molecule and allows photoproducts to be eliminated by the kidneys or the liver. Through phenomena known as photoisomerization and photo-oxidation, light transforms bilirubin into more water-soluble products.[21]

Bilirubin absorbs light ranging from 400 to 500 nm. This light wavelength penetrates the epidermis and reaches the subcutaneous tissue, so that only the bilirubin closer to the skin surface (up to 2 mm) is directly affected by light.[22,23] For this reason, there are several phototherapy devices to treat hyperbilirubinemia in the market. The most common are white fluorescent lamps, blue monochromatic lights and quartz halogen lamps with tungsten filament.[19]

To date, not much is known about the long-term impact of neonatal phototerapy in relation to the risk for melanocytic nevi in childhood and adulthood.[24]

The few existing studies about the correlation between the use of phototerapy in the neonatal period and the emergence of a larger number of melanocytic or dysplastic nevi throughout life show controversial results.[24-28]

Attention should be paid to a possible increase in the risk for the emergence of nevi in children who underwent phototerapy in the neonatal period. Phototherapy is still one of the cornerstones of the treatment for neonatal hyperbilirubinemia, a condition that may generate disastrous consequences if not adequately treated. However, there is a need for a larger number of studies that may correlate neonatal phototherapy and the risk for developing melanocytic and dysplastic nevi throughout life.

Prevention of damage caused by exposure to ultraviolet radiation

The incidence of skin cancer continues to increase, in spite of public health efforts to increase the adoption of safety measures in sun exposure.[14]

The major measures of safe behavior related to the sun recommended by several leading organizations in skin cancer studies include[14]: do not get burned; avoid tanning

and tanning salons; use protective clothing and hat; look for the shade; apply topical sunscreen; use UVR-protected sunglasses.

Shadow

Estimates show that 47% of daily sun exposure children receive occurs in outdoor areas in school breaks.[29]

A rule that may help identifying when the sun should be avoided is the "shadow rule" (Figure 2). The sun does more harm as smaller the child's shadow is in relation to the child's height, which indicates that the solar zenith has an incidence smaller than 45º. The bigger the size of the shadow, the smaller is the risk.[29]

Sunglasses

The major visual health organizations in the US recommend that sunglasses absorb from 97 to 100% of the full UVR spectrum (i.e., up to 400 nm).[14] It is recommended that people use sunglasses when they are in outdoor environments, driving, working, practicing sports, walking or jogging.[14]

Topical sunscreens

Topical photoprotectors and topical sunscreens are substances that absorb and filter UVR, dispersing and reflecting radiation.[29] Most sunscreens approved by the Food and Drug Administration (FDA) are organic chemical agents that absorb several UVR wavelengths, primarily in the UVB spectrum, while others are effective in the UVA range (Table 3).[14] Chemical photoprotectors absorb the energy conveyed by the UVR photons and so they may be considered exogenous chromophores.[29] They are very diverse, they have different mechanisms of action and they transform light energy into thermal energy. Some absorb especially UVB radiation, such as paraminobenzoic acid (PABA), which has a limited use due to adverse skin reactions such as contact dermatitis, in addition to cinnamates, salicylates and octocrylene.[29] Other absorb the UVA spectrum more, such as benzophenones, anthralin, avobenzone and terephthalylidene dicamphor sulfonic acid (Mesoryl SX®).[29] Some chemical (organic) agents absorb both UVA and UVB, such as Tinosorb M and Tinosorb S (methoxyphenyl triazine).[29] In general, these organic sunscreens are colorless and well-accepted cosmetically, although they may cause a higher number of contact dermatitis when compared to inorganic sunscreens.[29]

Figure 2 - "Shadow rule": best times for outdoor exposure, as indicated by the shadow of the children in relation to their height. Image obtained from the Word for Windows image database (Microsoft®)

The FDA approved two inorganic physical sunscreens for use in photoprotectors, titanium dioxide and zinc oxide.[14] Most inorganic screens have a white color or tint when applied to the skin. These screens are not irritant or photosensitizing, since they are post-inert that do not penetrate beyond the skin's corneal layer, with no systemic absorption. They should be used by people with a history of allergy to topical photoprotectors.[29]

Chemical screens absorb UVR energy and dissipate heat; physical screens reflect UVR (Figure 3).

Sunscreens, according to an American Academy of Pediatrics recommendation, are liberated for use after 6 months of life.[14] Up to 2 years of age, the use of physical sunscreens is preferable, since they are less allergenic in comparison to chemical screens. Sunscreen must be applied in the whole bodily surface before sun exposure and reapplied every 4 hours or earlier, in case excessive sweating or diving occurs. The recommended amount of sunscreen is 2 mg/cm^2.[14]

Sun protection factor

SPF is a grade system developed to quantify the degree of protection a topical sunscreen offers for the emergence of skin erythema.[14] The higher the SPF, the higher is the protection for erythema.[14] For example, an individual who presents skin reddening (erythema) after 10 minutes of sun exposure, by using a sunscreen with SPF 15 will develop erythema only after 150 minutes of sun exposure (10 minutes x 15).[14]

However, a sunscreen's SPF usually represents a protection smaller than expected, since usually less than half of the recommended amount of sunscreen, 2 mg/cm^2 of skin, is applied.[14]

Table 3 - Sunscreens approved by the FDA and protection spectrum

Active ingredient approved by the U.S. FDA	Maximum permissible concentration (%)	Range of protection (nm)	Provided protection (UVA/UVB)
Organic (primarily UVB protection):			
PABA	15	260-313	UVB
Padimate O	8	290-315	UVB
Octinoxate (octyl methoxycinnamate)	7,5	290-315	UVB
Cinoxate	3	280-310	UVB
Octisalate (octyl salicylate)	5	210-328	UVB
Homosalate	15	260-310	UVB
Trolamine salicylate	15	290-315	UVB
Octocrylene	10	287-323	UVB
Phenylbenzimidazole sulfonic acid	4	290-340	UVB
Organic (primarily UVA protection):			
Avobenzone	3	310-400	UVA_1/UVA_2
Meradimate	5	200-380	UVA_2
Sulisobenzone	10	250-380	UVB, UVA_2
Oxybenzone	6	270-350	UVB, UVA_2
Dioxybenzone	3	206-380	UVB, UVA_2
Ecamsule (terephthalylidene dicamphor sulfonic acid - Mesoryl SX®)	10	295-390	UVA_1/UVA_2
Inorganic:			
Titanium dioxide	25	290-350	UVB, UVA_2
Zinc oxide	25	290-400	UVB, UVA_1

Adapted from: Sambandan & Ratner.[30]
FDA = Food and Drug Administration; UVA = ultraviolet A; UVB = ultraviolet B.

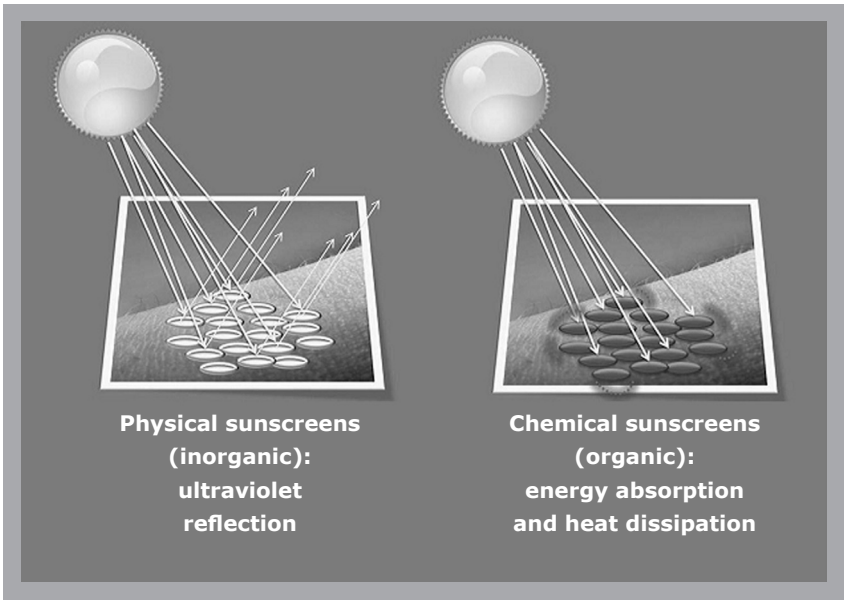

Figure 3 - Action of physical and chemical sunscreens in relation to UVR

SPF is an index to measure protection from UVB (which produces erythema), while protection from UVA is expressed by other media.[30]

Analogously to SPF, the minimal pigmentary dose (MPD) is the quantity of UVA needed to produce the first skin pigmentation after UVR exposure.[30]

The use of sunscreens with a SPF of 15 is considered adequate for most individuals, both children and adults. The exception is individuals with diseases caused or worsened by UVR, such as lupus erythematosus or xeroderma pigmentosum. In these cases, the use of the highest possible SPF is indicated, with the proviso that the risk for contact dermatitis is directly proportional to the SPF number.

Vitamin D and the use of sunscreens

UVB is necessary for the synthesis of active vitamin D.[30] At least about 90% of active vitamin D in each person is generated in this way.[30] However, humans can obtain vitamin D from other sources besides sun exposure, such as fortified milk, fish oil and vitamin supplements.[18] After sun exposure, 7-dehydrocholesterol in the skin is converted to previtamin D_3 and then to vitamin D_3 (cholecalciferol).[30]

A great debate occurred about a possible vitamin D_3 deficiency caused by the frequent use of topical photoprotectors.[30] Studies show that the adequate use of a SPF 15 sunscreen (2 mg/cm^2) reduces the synthesis of active vitamin D in 98%.[30] However, in clinical terms, a deficiency in vitamin D in relation to serum levels or function has not been found. That may be explained by some factors[30]: (I) acquisition of the necessary vitamin D through diet; (II) most people apply an insufficient amount of sunscreen; and (III) even when sunscreen is adequately applied, this application is not completely homogeneous, and some UVR still penetrates the skin.

Final recommendations

UVR is carcinogenic to the human skin and causes several other harmful effects.[14] Excessive UVR exposure in childhood or adolescence increases the risk for developing skin cancer. Pediatricians and dermatologists dedicated to children's integumentary diseases may have a relevant role to play by providing education on skin cancer and its prevention to patients and their parents or caretakers.[30]

It is especially important to approach this issue in what relates to children with a high risk for skin cancer (light-skinned children, those with nevi and/or ephelides and those with a family history of melanoma).[14] Melanoma is rare in children, but melanocytic nevi are not.[30] The issue of nevi and the necessity of paying attention to the changes they may suffer must be approached[14]; and, when puberty comes, the issue of artificial tanning and the harm it can do must also be approached.[14]

Children up to 6 months of age must not be exposed to direct sunlight.[14] The Australasian College of Dermatologists recommends the use of sunscreens in small children when sun exposure cannot be avoided by other means: "shade, clothing and wide-brimmed hats are the best measures to protect small children. Sunscreen must be applied in skin areas not protected by the clothes."[14] The American Academy of Pediatrics (AAP) also recommends the use of sunscreen in children of less than 6 months in small areas of skin, if adequate clothing and shade are not available.[14]

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