

SUN-TRAUMA PREVENTION

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In the past it has been the beneficent action of the sun's rays that has been greatly lauded. Cloudless Alpine spas acquired wonderful reputations for the treatment of tuberculosis. The therapeutic action was confirmed when first the bactericidal effect of ultraviolet radiation was proved; and later their stimulating effect on the metabolism, as demonstrated by the production of vitamin D in the irradiated skin of mammals. Only recently have the sun's rays come to be regarded by medical scientists as a public-health menace, particularly in the sun-drenched countries of the southern hemisphere.

SOLAR RADIATION

The ultraviolet rays of the solar spectrum range in wave-length from 500 Å to 3,900 Å, beyond which are the visible violet rays. But no rays of less than 2,800 Å wave-length penetrate our atmosphere to reach the surface of the earth. The natural ultraviolet rays that concern us are, therefore, those ranging from 2,800 Å upwards. The effects of these rays vary somewhat according to their wave-length. The shortest are most bactericidal, most traumatic (sunburn- and cancer-producing) and most vitamin-D producing. Sunburn and vitamin-D production end at 3,200 Å. Cancer production is believed to continue further along the spectrum to 3,340 Å.¹ Bactericidal action ceases at 3,600 Å. Melanin production does not start until 3,000 Å, but continues far up the visible spectrum to 6,000 Å, a useful fact, since we can thereby use that part of the spectrum beyond the sunburn and vitamin-D producing regions to invoke this protective mechanism of the skin.

TABLE I. SOLAR WAVE-LENGTHS IN ANGSTROM UNITS

<i>Ultraviolet radiation.</i>	500—3,900 Å
	2,800 Å reach earth—bactericidal, traumatic and vitamin-D producing
	3,000 Å melanin production starts
	3,200 Å vitamin-D production ends, sunburn action ends
	3,340 Å cancer production ends
	3,600 Å bactericidal action ends
<i>Visible radiation.</i>	Violet 3,900 Å +
	Blue 4,300 Å +
	Green 4,900 Å +
	Yellow 5,500 Å +
	Orange 5,900 Å +
	6,000 Å melanin production ends
	Red 6,200—7,700 Å
<i>Infrared radiation.</i>	7,700—5,000,000 Å

(Note: 1 millimicron=10 Angstrom units)

SUSCEPTIBILITY TO SUN-TRAUMA

Skin damage caused by the sun's rays may be either acute—the erythema of sunburn, often followed by blistering and peeling; or chronic—keratosis which may progress to basal or squamous-cell carcinoma.

Susceptibility to solar trauma varies greatly for both genetic and nutritional reasons. Very dark-skinned races are virtually immune because of the abundance of pigmented melanin. At the other extreme are albinos; then most redheads and a

particularly blond type of 'nordic'. The general state of the nutrition and particularly that of the skin is also important. It is with the latter of these that this study is mainly concerned. Individuals vary in their susceptibility according to habits; a long period of indoor living with its bleaching effect renders fair skins specially vulnerable.

1. Melanogenesis

The production of melanin is the function of the highly specialized melanocyte, which occurs as every fourth or fifth cell in the basal layer of the epidermis. It can be looked upon as a secretory cell manufacturing the deeply pigmented granules of melanin or melanosomes. It has numerous fine dendritic tubules spreading out among the prickle cells of the malpighian layer conveying melanosomes to them. The melanocyte hydroxylates the amino acid tyrosine into dopa (dehydroxy-phenylalanine) and ultimately into melanin. The catalyst tyrosinase is necessary for the hydroxylation of the precursor tyrosine into dopa.

Melanosomes are pigmented in relation to the amount of tyrosinase they contain. Exposure of the skin to sunlight produces darkening of the melanin. Ultraviolet and visible radiation up to 6,000 Å are concerned in this. As the sunburning rays end at 3,200 Å, it is possible to produce tanning of the skin while obstructing all the shorter sunburning ones.

This presumably is the aim of the vendors of the much-advertised protective cosmetics: lotions, ointments, oils, creams, sprays and foams. Most of these are effective only in that they lessen the amount of penetration of *all* ultraviolet rays, thus diluting the total irradiation. The same effect is attained by carefully graded periods of exposure of the body to the sun, starting with a very short period on the first day. A few cosmetics do screen off the most damaging rays, while allowing the tanning rays to pass. A careful study of the commonly advertised preparations made by the strictly impartial journal *Which?* showed that the most expensive ones were not very effective.

A very valuable contribution has, however, been made by Loewenthal,^{2,3} who demonstrated that the drug triprolidine taken by mouth obstructed the rays with wave-lengths of less than 3,200 Å. It is apparently deposited below the stratum corneum where it absorbs the short-waved ultraviolet rays for a day or two. This provides a much pleasanter method of combating painful erythema than the use of sand-collecting ointments and creams. It has, however, the drawbacks of most antihistaminic drugs, including the production of drowsiness. Alcohol, a not infrequent holiday luxury, is contraindicated because of increased sedation.

The most rational method of combating sunburn, apart from limiting exposure to graduated daily doses, would seem to be improving the nutritional condition of the skin to assist it in its protective functions. Where there is genetic impairment of melanogenesis, little can be done apart from greatly restricted living with minimal exposure to sunlight.

The albino with his inability to produce pigmented melanin in the skin can achieve only partial protection, reacting to exposure by a thickening of the outer horny layer. To a

somewhat lesser extent this applies also to many redheads and 'sandy' nordics. All of these can produce only very limited pigmentation—various degrees of freckling. Artificial protection is provided by indoor living, covering of exposed skin and the wearing of wide-brimmed hats. Albino Bantus, precluded for economic reasons from such a protected existence, are in a most unhappy position. Their high mortality from skin cancer was reported as far back as 1911.^{4, 5}

2. Nutritional Deficiency

Various skin conditions, primarily the result of protein, vitamin or mineral deficiency, are made manifest or are exacerbated by solar irradiation. Strict vegetarians are often found to be particularly vulnerable. This is probably owing to the low content of many essential amino acids in vegetable proteins, and the common deficiency in the diet of vitamin A. Vegetarians who in the past have suffered severely from sunburn have been greatly helped by a course of amino acid tablets and vitamin A tablets.

Farmers and others exposed continually to the mostly cloudless skies of the inland plateau of South Africa, should have particular attention paid to their general nutrition, if serious sun-trauma is to be avoided as an occupational hazard.

Since vitamin A is essential for the maintenance of normal epithelial integrity, and is believed to be concerned in melanin and keratin formation, adequacy is surely of importance.

Excessive irradiation produces excessive vitamin D with its calcium-fixing effects. It is possible that much of the available calcium is fixed elsewhere than in the skin. The late Prof. A. S. Strachan, during the course of many thousand necropsies performed at the S.A. Institute for Medical Research, had collected a significant number of cases of comparatively youthful persons, who had lived outdoor lives, with calcareous deposits in the necrosed intima of the arteries.⁶ Could it be that our generous South African sun is responsible for an additional trauma: deposition of calcium where it is damaging, meanwhile depriving the skin of this essential mineral?

Vitamin A

We do not yet understand the biochemical role of this highly complex, rather unstable pentane alcohol in maintaining the status of various epithelia. It is plentiful in fish-liver oil, milk fat and many pigmented vegetables; it is now produced synthetically. The international unit of vitamin A equals in activity 0.6 μg . of pure carotene.

There is evidence that excess of vitamin D inhibits the action of vitamin A. A possible explanation for this has been discussed above.

The skin conditions of persons known to have been deprived of vitamin A have been frequently and clearly described. It includes dryness, scaliness, furunculosis appearing first antero-laterally on the thighs and postero-laterally on the arms; finally the eruptions occur over the entire integument. The skin manifestations of known deficiency are at least partially responsible for these lesions. This is evidenced by the results of treatment with large doses of vitamin A of keratosis follicularis, ichthyosis, congenital ichthyosiform erythroderma and rubra pilaris. The improvement is demonstrable clinically and histopathologically. A striking accentuation of the granular layer was observed histologically in these cases.

Vitamin-A Tablets

Preparations of vitamin A have long been used by clinicians for the prevention and treatment of sunburn, reportedly with con-

siderable benefit. My own first observations were made in December 1959 on a group of 12 fair-skinned students, using tablets of 25,000 I.U. synthetic vitamin A. All of them had during a previous seaside holiday, after an intensive period of indoor studying for the November examinations, suffered from severe, painful erythema followed by blistering in some and peeling in all.

They were instructed to take two tablets each, on the night before the first day of bathing and sun-bathing. If painful erythema occurred, they were to take two tablets at hourly intervals until there was complete relief. All experienced erythema, mild in 8 who continued with the nightly tablets, and did not peel or only slightly. Two had painful erythema, relieved by 4 and 6 further tablets during the day; nightly tablets thereafter resulted in slight peeling. The remaining 2 had very painful erythema not relieved by further tablets. They discontinued the experiment and thereafter exposed themselves for only very short periods, but still took the nightly tablets. Both had extensive peeling.

This experiment was designed to test the theory that the stress of ultraviolet radiation made extra metabolic demands on the skin, producing a relative vitamin-A deficiency, which might be relieved by a timely additional supply of the vitamin.

Last July Prof. F. E. Camps, Reader in Forensic Medicine, London University, told me of a similar experiment he had carried out with volunteer medical students, using, however, much more potent artificial irradiation.⁶ Six students had the right inner-arm exposed at a distance of 12 in. to ultraviolet radiation, using a Phillips Biosol 250-watt lamp with a zonder dorno filter. This restricts the wave-length in the emission to 2,800 Å and above. After 4 minutes of exposure, 3 of the students developed third degree and 3 second degree erythema. Later he repeated the experiment with the same 6 students, but this time after the previous administration of 25,000 I.U. synthetic vitamin-A tablets. He reported that reactions now, following 4 minutes of exposure, were markedly different: only 1st degree erythema in 3, and 2nd degree in 3 of the students occurred.

In other experiments over longer periods, Professor Camps found that the vitamin tablet prevented sunburn even though erythema developed; but there was no reduction in the suntan effect of the irradiation.

Vitamin A plus Calcium

The observations with vitamin-A supplement, while indicating that many fair-skinned persons would be assisted by their use, were not conclusive. During the following 4 years, a calcium-enriched tablet was used on volunteer groups. This tablet, known as 'sylvasun', consists of 25,000 I.U. vitamin A and 2 grains of colloidal (assimilable) calcium carbonate.

The students in all 4 groups were predominantly fair-skinned, and had during a previous seaside holiday suffered from sunburn. They were in good health, apart from some signs of fatigue and bleaching of the skin, that could be expected after a period of intensive study in preparation for the November examinations. They were carefully questioned regarding drugs, especially tranquilizers and amphetamines. I was assured then, and subsequently confirmed, that none would be or were taken during the seaside holidays.

They were instructed to take 2 tablets each night before exposure and 2 tablets hourly, on the first day of sunbathing, should painful erythema develop. Except for 3, who should never have been included in the experiment, the treatment was remarkably successful.

The 3 exceptions were two redheads and a blonde who had, on the very rare occasions of exposure, suffered from extremely painful erythema followed by blistering. They might in fact be looked upon as near-albinos, with virtually no mechanism for the production of pigmented melanin. The experiment was designed to ascertain whether in persons with normal melanogenetic equipment, skin protection could be produced sufficiently quickly to prevent sunburn.

Excluding these 3, a total of 104 students carried out my instructions. The results can be briefly summarized: In 62 there was little or no reddening during the first day. No curative tablets were taken and a satisfactory tan was quickly attained.

28 of the students, becoming aware of some erythema on the first day, took 2 tablets after about an hour. Without any further tablets except the nightly 2, their progress was uneventful, a good tan developing.

In the remaining 14 the erythema on the first day was more marked and in some even slightly painful. This was completely

relieved by the taking of 6-8 tablets during the first day. A tan was produced, as with the others, without any peeling.

Controls were provided by these students themselves because of the painful sunburn and peeling which had been experienced during a previous exposure. Further unintentional controls were 22 students, who had forgotten all about my talk to them a month previously and the tablets which had been issued to them. They all paid the usual price of sunburn followed by peeling. Some of them belatedly got hold of tablets, but not in time to prevent the worst effects of their negligence.

Toxic Effect of Excessive Dosage

Virtually any form of therapy is liable to gross abuses by ignorant unsupervised patients. That it may also occur as a freak condition with vitamin-A therapy is mentioned here only because of the fears aroused in the public mind by an entirely unrelated occurrence. In spite of the very high doses used by Graham *et al.*,⁷ up to 1,000,000 units daily for 10 weeks, the signs of toxicity observed were few and transient; the side-effects, which occurred in only three of his 16 subjects, were respectively headache, dry skin with itching, and loss of appetite with insomnia. It is only in children that serious interference in bone-growth has been recorded, and then only in circumstances of gross irresponsibility. The child at the Children's Memorial Hospital in Chicago reported by Pease (and featured in *Time* as an interesting occurrence, so soon after the thalidomide tragedy) had been receiving 3 teaspoonfuls of the vitamin-A preparation daily, approximately 50 times the dose prescribed by her doctor. Our present knowledge regarding vitamin-A deficiency is summarized in the 1963 edition of the Excerpta Medica Foundation's *Side Effects of Drugs*.⁹

In the prevention and treatment of sunburn it is only on the first day of exposure that the vitamin A ingested in tablet form might amount to more than 200,000 I.U. The amount taken nightly thereafter for 3 or 4 days is 50,000 I.U. units.

As toxicity results only from prolonged intake of massive doses, it does not have to be considered in the treatment of sunburn.

DISCUSSION

The assumption seems justified that the skin of a normal healthy person is able to withstand quite severe ultraviolet irradiation provided it is in an adequate state of nutrition. The degree of nutrition required is, however, much higher than that sufficing for general health. Severe irradiation reveals deficiencies in vitamin A and calcium supply which otherwise have no overt effect. In other words, a diet which is adequate for ordinary indoor living, particularly in countries

of low illumination, is inadequate for outdoor living in countries like South Africa and Australia; and even for northern climates when the exposure is sudden after a lengthy period of indoor non-irradiated living.

In albinos, many red-haired and some excessively blond persons, the mechanism for the production of pigmented melanin is virtually absent: in them no amount of the accessory food substances involved can produce the necessary tanning. They can only obtain the slight protection of a thickened stratum corneum.

Persons in a poor state of health, or in a period of special demand on the metabolism may not be in a condition to be adequately helped by an addition to the diet of the accessory substances concerned. This field study has, however, demonstrated that normal healthy young men and women with fair skins can be protected from the effects of severe exposure to the rays of the sun by a considerable previous addition to the diet of vitamin A and assimilable calcium.

SUMMARY

The sunrays of short wave-length that reach the earth promote health in that they are bactericidal, and, by activating precursor substances into vitamin D, promote calcium-phosphorus metabolism. In sun-drenched climates, particularly of the southern hemisphere, they have become recognized as a serious hazard to health, producing in unprotected persons sunburn as an acute condition and keratosis in the long term. The latter condition not infrequently leads to basal or squamous-cell carcinoma.

The healthy skin reacts protectively to irradiation by thickening of the stratum corneum and the production of pigmented melanin. Vitamin A, which is essential for the maintenance of epithelial integrity, is presumably concerned in this reaction. Excess vitamin-D production during irradiation may combat this reaction by lessening the amount of calcium available to the skin.

A series of 104 fair-skinned students was protected during seaside holidays by ingestion of a vitamin-A—calcium supplement.

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