Sunlight, tanning booths, and vitamin D

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INTRODUCTION

This conference was sponsored by the American Academy of Dermatology Association to evaluate the risk/benefit ratio for exposure to natural and artificial sources of ultraviolet (UV) radiation, and to review the scientific, clinical, social, and regulatory issues relating to vitamin D and health.

The following presentations were made: biologic effects of UV; role of vitamin D in human health and sources of vitamin D; amount of sun exposure in daily activity; US Food and Drug Administration (FDA) guidelines for the indoor tanning industry, tanning beds, and the risk of melanoma; and use of indoor tanning facilities by adolescents, including enactment and variable enforcement of legislation restricting minors' access to indoor tanning. Discussion of these topics was held, followed by a summary and conclusion session.

EFFECTS OF ULTRAVIOLET RADIATION

Barbara A. Gilchrest, MD (Boston, Mass), reviewed the effects of UV exposure on normal skin. Well-established acute effects include DNA damage with substantial but incomplete repair, UV-induced erythema and sunburn reaction, delayed tanning, photoimmunosuppression, and pre-vitamin D_3 synthesis.[1-3] Action spectra for UV-induced erythema, delayed tanning, cyclobutane pyrimidine dimer formation, and vitamin D_3 (cholecalciferol) synthesis are very similar, all with a peak in the UVB range.[2-6] It should be noted that UV-induced vitamin D synthesis (specifically, the generation of pre-vitamin D_3 from 7-dehydrocholesterol) is maximal at suberythemal UV doses, and further UV exposure does not increase pre-vitamin D_3 levels but rather increases conversion of pre-vitamin D_3 to lumisterol and tachysterol, which are biologically inert compounds.[7] Furthermore, the vitamin D_3 that is formed by thermal isomerization from pre-vitamin D_3 is photolabile; if the amount synthesized exceeds the amount leached into circulation, the remaining vitamin D_3 in the skin is degraded by further sun exposure.[8] In contrast, during prolonged UV exposures, the severity of sunburn and formation of DNA photoproducts, such as cyclobutane pyrimidine dimers, increase continuously.

Vitamin D_2 (ergocalciferol) is present in plants. It is an active ingredient of some of the commercially available vitamin D supplements. The biologic activity of vitamin D_2 and vitamin D_3 in humans is identical; therefore, the term "vitamin D" will be used throughout the rest of this manuscript.

A 2004 study explored possible motivations for tanning aside from the desire for a more cosmetically pleasing, darkened skin color.[9] The investigators recruited 14 adults who were frequent users of indoor tanning facilities. On Monday and Wednesday,

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the subjects were exposed to both UV and sham UV radiation in identical appearing tanning beds, and on Friday of each week they were allowed to choose one of the light sources for an additional exposure; of the 41 possible choices, 39 were for UV radiation, with better "relaxation" as the most frequently cited reason. This suggests that at least some individuals (those who choose to use indoor tanning facilities) perceive a nonvisible benefit. One possible explanation for UV acting as a "relaxing" reinforcing stimulus is the epidermal production and release following UV radiation of beta-endorphin,[10] an opioid best known to be released from the pituitary gland and to be responsible for the sense of well-being after vigorous exercise, the so-called "runner's high."[11]

Long-term effects of UV irradiation include photoaging and photocarcinogenesis. Skin cancer comprises one-half of all cancers in humans. In the United States in 2005, it has been projected that there will be more than 1 million new cases of basal cell carcinoma, more than 200,000 new cases of squamous cell carcinoma, more than 59,000 new cases of invasive melanoma, and a projected 7700 deaths related to melanoma.[12] The cost of management of skin cancers is estimated to be more than $800 million per year in the United States alone. Photoaging has a far higher prevalence and is nearly universal among middle-aged and elderly whites. Moreover, expenditures for medical and surgical treatment of photoaging far exceed those for skin cancer.

Response to UV is dependent on skin phototype, an empirical classification based on the individual's expected sunburn and suntan responses to a first moderate sun exposure after a long period of nonexposure (eg, 30 minutes on the first sunny spring day).[13] Skin phototypes I and II individuals are generally but not always very fair-skinned with red or blond hair and blue or green eyes, and they characteristically freckle during childhood. Given sufficient lifelong UV exposure, they are at high risk of photoaging and skin cancer, including melanoma. Skin phototypes V (Hispanic, Indian, or Asian) or VI (black) individuals are generally dark complexioned, capable of dark tanning, and are at a relatively low risk of chronic UV damage. Persons with phototypes III and IV are generally intermediate in baseline complexion, tanning capacity, and vulnerability to long-term UV damage. In general, the rate of vitamin D photosynthesis varies inversely with skin phototype,[14] at least in part because melanin pigment in the epidermis absorbs the UV photons otherwise responsible for photochemical reactions such as pre-vitamin D_3 production. Thus, brief sun exposures often permit maximal vitamin D production in fair-skinned individuals but may allow only submaximal vitamin D production in dark-skinned individuals. The elderly also produce less vitamin D than young adults after the same amount of exposure to solar simulated radiation and hence have lesser increases in serum 25-hydroxyvitamin D levels,[15] presumably because their epidermis is thinner and contains less of the source compound 7-dehydrocholesterol. Unfortunately, the elderly also have less proficient DNA repair after each UV exposure,[16,17] likely increasing their already high risk of photocarcinogenesis from cumulative lifelong UV damage.

Kevin Cooper, MD (Cleveland, Ohio), reviewed the effects of UV on the immune system. Repetitive exposure to UV results in photochemical reactions which activate both the innate and adaptive arms of the immune system, and modify the functions of Langerhans cells, mast cells, and dermal antigen-presenting cells.[18] In both humans and mice, the signaling cascade changes the skin microanatomic environment such that cellular functions of both constitutive and newly arriving cells are altered.[19] For instance, blood monocytes chemoattracted into sun-exposed skin encounter deposits of complement protein C3 that has been activated to become iC3b, and the resultant signaling through the iC3b receptor, CD11b, arrests their differentiation into replacement Langerhans cells (UV acutely depletes Langerhans cells), but promotes their differentiation into activated macrophages.[20] These monocyte-macrophages are critical for a number of key events in UV-exposed skin, including the production of immunomodulating cytokines (ie, interleukin 10 [IL-10]), induction of immune suppression, and production of tissue-modifying cytokines, such as IL-6.[21] Consistent with the known capabilities of macrophages for protease production and inducing oxidative damage, inactivation of the monocyte-macrophages results in reduction of epidermal damage following UV injury.[22] In fact, the UVB-induced recruitment of CD11b+ macrophages and polymorphonuclear cells into murine skin represented the dominant cellular source of oxidative stress to the tissue.[23]

In human subjects, as in mice, acute exposure to solar simulated radiation resulted in a UV–dose dependent inhibition of contact hypersensitivity immune responses.[24] Interestingly, high levels of vitamin D receptor signalling can also cause immunosuppression in human skin.[25] This suggests that excessively high levels of serum 25-hydroxyvitamin D may in fact add to the tissue's burden of immunosuppressive events that occur after UV injury, and further diminution of the tumor immune surveillance capacity of the skin's immune system.

The ability to quantify immune suppression in humans enables the determination of an immune protection factor (IPF) of sunscreens in human subjects; the IPF correlated well with protection against UVA, but did not correlate with sun protection factor (SPF), which is a reflection of protection against erythema, a biologic response predominantly caused by UVB.[26,27] The IPF is therefore useful in detecting not only UVB injury but also injury responses that may be poorly detected by SPF, such as those induced by UVA and the propensity of UVA to generate reactive oxygen species.[28]

Antioxidants appear to play a role in down-regulating the photocarcinogenic effect of UV. A plant-derived antioxidant, silymarin, has been shown to prevent UVB-induced photoimmunosuppression in a mouse model.[29]

In summary, solar radiation UV photons have direct damaging effects on molecules and cells, including DNA, proteins, and lipids, which cause immunosuppression, photoaging, and photocarcinogenesis, and possibly exacerbation of infections.

BIOLOGIC EFFECTS AND SOURCES OF VITAMIN D

Heike A. Bischoff-Ferrari, MD, MPH (Boston, Mass), presented an overview of this topic. The most established beneficial effect of vitamin D is improved bone health and fracture prevention.[30-32] In addition, vitamin D appears to directly improve muscle health[33,34] and reduce the risk of falling in older persons.[35] Further primarily epidemiologic evidence of a beneficial effect of vitamin D exists for colon cancer,[36] multiple sclerosis,[37] insulin resistance,[38,39] other cancers,[40-43] osteoarthritis,[44,45] hypertension,[46-48] and periodontal disease.[49]

One major source of vitamin D is sun exposure, with an action spectrum peaking in the UVB (290-320 nm) range. Exposing 5% of the uncovered body surface twice a week in summer may be equivalent to an intake of 430 IU of vitamin D per day; however, for a given surface area, a plateau is reached after 20 minutes.[50] The potential of vitamin D production in the skin declines with age,[51] and has been reported to be insufficient, during the winter months, to reach optimal requirements in both younger and older adults.[52,53] Other sources of vitamin D, which do not carry an increased risk of photoaging and skin cancer, are vitamin D supplements or food sources supplemented with vitamin D. Multivitamins usually contain 400 IU of vitamin D per tablet, but there are also separate vitamin D supplements, several combined with calcium. In the United States, milk contains about 400 IU of vitamin D per quart (ie, 100 IU of vitamin D per 8-oz glass). Natural food sources of vitamin D are few, with more substantial amounts gained through the consumption of fatty fish (eg, 3.5 ounces of salmon and mackerel each contain 360 IU of vitamin D).

Recommended vitamin D intakes are 200 IU/day for young adults, 400 IU/day for those aged 51 to 70 years, and 600 IU/day for those over age 70 years.[54] However, several studies suggest that these recommendations may fail to bring most of the population up to desirable serum vitamin D levels (measured and expressed as 25-hydroxyvitamin D levels) of 80 nmol/L.[53,55,56] Several vitamin D experts have proposed a threshold level of 80 nmol/L 25-hydroxyvitamin D for optimal bone health, at least in the elderly.[57] It should be noted, however, that estimates of the 25-hydroxyvitamin D threshold level cited in textbooks vary widely from 20 to 110 nmol/L (9-38 ng/mL).[58-63] Intake of 700-1000 IU vitamin D per day in younger and older adults may bring 50% of the population up to 80 nmol/L.[53,55,56] The safe upper intake has been set at 2000 IU per day by the National Academy of Science.[54]

AMOUNT OF SUN EXPOSURE IN DAILY ACTIVITY

Darrell S. Rigel, MD (New York, NY), presented data on this topic. Studies done in Northern Europe used standard erytherma dose (SED) to quantify sun exposure. One SED was defined as an erythema weighted exposure dose of 100 J/m^2. In subjects with skin phototypes I-IV, it would require an exposure between 1.5 and 6 SED to produce a minimal erythema on unexposed skin. It was estimated that in Northern Europe, indoor workers received an annual exposure of around 200 SED; this exposure occurred primarily from weekend and vacation exposure, and principally to the hands, forearms, and face.[64] Outdoor workers at the same latitudes received doses about 2 to 3 times higher. In a study of the activity profile of over 9000 individuals in the United States over 24 months, it has been estimated that the average UV doses these subjects were exposed to was 25,000 J/m^2 per year.[65] A study of 3449 Canadian adults (>25 years old) reported that 51% of the subjects were exposed to daily sunlight for a duration of between 30 minutes and 2 hours, and 26% were exposed for more than 2 hours.[66] Using personal digital dosimeters, studies in 4 high school students in the New York metropolitan area showed that the average UVB exposure was enough to cause erythema in fair-skinned students.[67] Similar studies among Alpine skiers in Vail, Colo, showed that these subjects were exposed to 0.5 to

7.6 times the minimal erythema dose (MED) per day.[68]

A recent study asked 85 subjects to record their activity and exposure to sunlight for 1 week in December in New York, Chicago, Fort Lauderdale, San Diego, and Vail. The participants were exposed to an average of 40 ± 6 min/day of sunlight on weekdays, and 123 ± 21 min/day on weekend.[55] The authors calculated that even if all subjects effectively used an SPF15 sunscreen in a manner to obtain full protection, their effective UV-exposure dose would be reduced by 93%, which would correspond to 2.8 minutes and 8.6 minutes of sun exposure per day for the weekdays and weekend, respectively; this corresponds to 31 minutes of sun exposure per week. It has been calculated that for individuals with skin phototype II, 5 minutes of noontime summer sunlight exposure 2 to 3 times a weeks is more than adequate to satisfy the body's requirement for vitamin D.[70] Therefore, the result of this latest study suggests that this level of sun exposure was easily achieved through incidental exposure.

In summary, Dr Rigel concluded that existing studies on sun exposure duration or dose demonstrated that incidental UV daily exposures appear to be greater than required to achieve adequate vitamin D level, even given the recently suggested increase for the minimum normal serum 25-hydroxyvitamin D level.

FDA GUIDELINES ON THE INDOOR TANNING INDUSTRY

W. Howard Cyr, PhD, and Sharon Miller (Rockville, Md) presented an overview or the FDA guidelines. The US indoor tanning industry is a $3 billion per year enterprise, with about 25,000 tanning salons. In addition, there are numerous sun lamps and tanning beds available for home use. It is estimated that there were 27 million visits to tanning salons in 1999. The majority of customers are young women, age 20 to 39 years old. The peak business period is early spring.

Because of the known health risk associated with UV exposure, the medical community has advocated that sunlamps should be banned for all but medical purposes. Others, including the FDA, concluded that the hazards from sunlamps are similar to those from solar UV exposures, which are common and difficult to control. The FDA decided to regulate sunlamps with a performance standard "to protect the consumer from acute burns (as evidenced by erythema) and from exposure to hazardous radiation that is unnecessary for skin tanning."

The FDA regulations on sunlamps and sunlamp products can be found in 21 CFR 1040.20 (Chapter 21 of the Code of Federal Regulations, Part 1040.20) and also at the following web site: http://www.fda.gov/cdrh/radhlth/index.html. The regulations include requirements for a warning label, user instructions, limits on levels of UVC light, protective eyewear, and a timer system. The regulations were last amended in 1986.

In 1999, the FDA asked the public for comments and data on possible changes to the Sunlamp Performance Standard. Since that time, FDA has embarked on research to improve the recommended exposure schedules. In addition, progress has been made on the issue of testing and labelling suitable replacement lamps by working with the International Electrotechnical Commission (IEC).

In 2003, the FDA Center for Devices and Radiological Health (CDRH) proposed 6 amendments to the Sunlamp Performance Standard. These changes include: making the warning label more precise, including the warning label in catalogues and other indoor tanning materials, changing the definition of "manufacture" to include those who modify sunlamp products, creating protective eyewear specifications, modifying the action spectrum, and implementing standards for replacement lamps. An FDA advisory committee recommended moving forward with all 6 proposals, with minor modifications.

Dr Cyr indicated that sunlamp products are regulated under the Food and Drug Cosmetic Act as Class I medical devices. They are classified as UV lamps for tanning purposes only; no other medical or health claims can be made. Advertising claims are regulated by the Federal Trade Commission, which has likewise banned health claims. It should be noted that production of vitamin D by UV radiation requires doses that are considerably less than those usually obtained in a tanning session. There may also be differences in the spectral output of a lamp compared to sunshine and in the intensity of the lamp compared to the sun, so that a direct comparison in time between the sun and a sunlamp cannot be made.

Vincent DeLeo, MD (New York, NY), stated that compliance with the FDA guidelines among tanning booth operators is poor. In a survey of 50 tanning facilities in North Carolina, the recommended dose limits were exceeded by 95% of patrons, and 33% of them started tanning at the maximum doses recommended for maintenance tanning.[71] The average output of the lamps was 192.1 W/m^2 for UVA and 0.35 W/m^2 for erythemally-weighted UVB. Compared to the output of the summer noontime sun in Washington, DC, the average UVA output of the tanning bed was 4-fold higher, and the UVB output was 2-fold higher. It is recognized that the

FDA is developing dose recommendations and a treatment schedule that will allow tanning to be as safe as possible while warning the consumer about the side effects of UV exposure.

TANNING BEDS AND THE RISK OF CUTANEOUS MELANOMA

Tim K. Lee, PhD (Vancouver, British Columbia, Canada), presented a study on the association of tanning bed use and cutaneous melanoma.[72] A Medline search (January 1984 to April 2004) was performed, and systematic review and meta-analysis of the selected articles were performed. Selection criteria included case-control or cohort studies presenting "ever vs. never exposed" data, and studies that clearly state the number of exposed subjects, odds ratios, and 95% confidence intervals; studies involving psoralen plus UVA were specifically excluded. A total of 10 studies fulfilled the criteria and were included. The results showed that the use of tanning beds increases the risk of cutaneous melanoma (summary OR: 1.25, 95% CI: 1.05-1.49), and the risk appears to be higher if use begins early in life (summary OR: 1.69, 95% CI: 1.32-2.18); although it was not directly testable, the data suggest that there is a dose—response relationship between exposure and melanoma. A similar conclusion was reached in a recent review of tanning bed use and malignant melanoma.[73]

THE USE OF INDOOR TANNING FACILITIES BY ADOLESCENTS

Catherine Demko, PhD (Cleveland, Ohio), presented studies on this topic. A 1994 study in Minnesota first brought attention to indoor tanning among adolescents by reporting that 34% of area high school students had used artificial tanning lamps, some of whom reported burning, skin irritation, and other adverse events.[74] Subsequently, other studies among US adolescents demonstrated a positive association between indoor tanning and being female, increasing age, favorable attitudes about tanning, and a parent/guardian who tans indoors.[75,76] A nationwide survey of 6903 non-Hispanic white adolescents revealed that 37% of girls and 11% of boys had used an indoor tanning facility at least once in their lifetime; 28% of the girls had tanned indoors three or more times. Older teens, those residing in rural areas, and those who reported the use of tobacco or alcohol were also more likely to be indoor tanners.[77] In addition, teens who report indoor tanning are far more likely to sunbathe outdoors, further increasing their UV exposure. Taken together, studies consistently report that indoor tanning among US teens, particularly females, is significant and motivated in part by a desire to improve appearance. The message targeting teens, as well as adults, for safe UV exposure from all sources needs to be strengthened.

RESTRICTING MINORS' ACCESS TO INDOOR TANNING: PRECEDENT AND IMPLICATIONS

Laura Saul Edwards (Washington, DC) gave an overview of restricting access for minors to tanning booths. Federal law requires that US Surgeon General warnings be placed on the labelling for all tobacco products and alcohol products. The warning label for tobacco, required for more than 30 years, clearly states that tobacco causes cancer and other adverse events. In 1988, US Surgeon General C. Everett Koop, MD, announced that nicotine, a component of tobacco products, is addictive. An FDA effort to establish a national ban on tobacco use by individuals under age 18 was defeated by the US Supreme Court in 1996 (FDA *v* Brown and Williamson, Corp). Despite this setback, national youth smoking rates have steadily decreased, dropping from 36% in 1997 to 22% in 2003.[78] The reduction in youth smoking rates is widely attributed to the combination of Surgeon General warning labels and age limits enacted primarily by state governments.

The warning label for alcohol clearly states the risk of birth defects if used during pregnancy, possible health problems, and impairment while operating machinery and cars. In 1984, a national minimum drinking age law was enacted that requires all states to adopt a minimum drinking age of 21 as a condition of receiving federal highway funds. The Institute of Medicine reports that the minimum drinking age has significantly reduced fatal traffic crashes and the number of arrests of people driving under the influence and self-reported drinking by minors.[79] Reports made by the Congressional Research Service (CRS) and the Institute of Medicine show that drunkenness, driving under the influence, and general inebriation is higher in many European countries where the drinking age is lower than 21 years.

UV radiation is a known human carcinogen,[80] as is tobacco. Emerging evidence indicates that indoor tanning is addictive.[9] In addition, as with tobacco and alcohol use, a number of adverse health effects are linked to indoor tanning, including squamous cell carcinoma (OR: 2.5), basal cell carcinoma (OR: 1.5),[81] and as presented earlier in this article, melanoma.[72,73]

At the time of this writing, 22 states have adopted some form of age limits on indoor tanning, of which only California, Illinois, and Wisconsin have absolute bans in effect for children under a certain age (14, 14, and 16 years, respectively).[82,83]

Age limits enacted by the federal and state legislatures have reduced smoking and alcohol consumption by minors. The success of these age limits, and the known adverse health effects observed in tobacco, alcohol, and indoor tanning use provide a compelling precedent for establishing a national age limit for access to indoor tanning parlors and the use of sunlamps.

BREAKOUT SESSION

A breakout session moderated by Martin Weinstock, MD, PhD (Providence, RI), and Antony Young, PhD (London, England), was held to discuss the risk/benefit ratio of UV exposure to achieve an adequate vitamin D level.

SUMMARY*

Evidence developed in recent years shows that vitamin D levels in substantial segments of the US population are below those associated with optimal health.[84] For musculoskeletal health, for which there is a substantial body of evidence that vitamin D is important, the evidence reviewed indicates that level of 80 nmol/L of 25-hydroxyvitamin D is optimal, at least in the elderly.[57] However, estimates of the 25-hydroxyvitamin D threshold level cited in textbooks vary widely from 20 to 110 nmol/L (9 to 38 ng/mL)[58-63]; therefore, whether 80 nmol/L of 25-hydroxyvitamin D is the level that should be recommended for all adults remains to be determined. The evidence for benefit from a vitamin D level above the long-standing normative values for vitamin D stores is strong for the elderly population, among whom bone density and risk of falling is particularly important.[35]

Recently, sun exposure was reported to be associated with a decreased case fatality from melanoma.[85] The authors suggested that vitamin D may play a protective role, or alternatively that people who developed melanoma in the setting of high levels of sun exposure overall had a higher proportion of less aggressive form of melanoma. Unfortunately, the study did not take into account the higher incidence of melanoma in patients with high levels of sun exposure, a factor that likely more than compensates for any reduced fatality rate in number of total melanoma deaths. Nevertheless, this is a topic that needs to be studied further.

There are two major sources of vitamin D. One is oral ingestion either of dietary supplements or of food fortified with or naturally containing vitamin D. The second is photosynthesis of vitamin D from either solar UVB radiation or artificial UVB sources.

The current American diet alone is frequently inadequate to achieve the vitamin D levels suggested above. The situation is particularly complex for individuals with brown or black skin who are more frequently lactose intolerant and therefore consume less milk, one of the main dietary sources of vitamin D. That subpopulation also has skin that is less efficient at photosynthesis of vitamin D than those with white skin, and because of this they more commonly have lower vitamin D levels.[14,86] Supplements containing vitamin D and foods fortified with vitamin D can be effective in increasing levels. Concerns with supplemental vitamin D include difficulty in achieving consistent compliance, the potential for overdosing, and for interactions between vitamin D and other components. Supplements are quite inexpensive, but not free. Increasing the amount of fortified foods, or the amount of fortification in foods, is possible.

With respect to the photosynthesis of vitamin D, this process is maximized after 20 minutes of exposure to UVB, and the amount of vitamin D generated can be substantial if large areas of the body are irradiated.[50] The required dose of UVB is substantially lower in those persons with white skin, compared to those with dark skin.[14,86] The skin of the elderly is less effective at photosynthesis of vitamin D than the skin at younger ages.[51] Several studies have shown that current levels of incidental UVB exposure are inadequate for many people in the United States to achieve the serum level of 80 nmol/L of 25-hydroxyvitamin D mentioned above.[51,84] However, studies on duration or dose of incidental sun exposure indicated that subjects had more that adequate sun-exposure time or UV dose needed for the current recommended vitamin D level.[64-69] The reason(s) for the lack of correlation between these two sets of studies remains to be clarified. Artificial sources of UV vary tremendously in the amount of UVB they contain, and the consumer of that radiation cannot determine that amount from examining these devices. Exposure to UVB also has a series of well established and potentially severe hazards, including skin cancer and other forms of skin damage, eye damage, and infection.

*The participants of this conference includes members from the US Food and Drug Administration who gave a summary of the regulations on sunlamp products. Because some of the recommendations of this conference involve possible petitions to the FDA with regards to sunlamp products and also with regards to adequate levels of vitamin D, the FDA participants must officially remain neutral with regards to those recommendations.

While there are FDA regulations on sunlamps, compliance with these guidelines among tanning booth operators is poor.[71] The use of tanning beds is known to be associated with the development of squamous cell carcinoma, basal cell carcinoma, and melanoma.[72,73,81] UV is a known carcinogen.[80] In view the common use of tanning facilities by adolescence,[74-77] the American Academy of Dermatology Association believes that restricting minors' access to indoor tanning, similar to that of tobacco use, is an appropriate public health policy.

CONCLUSION

The conference's participants reached the consensus that, based on increasing documentation of vitamin D benefits, it is timely to review public health policy with regard to recommended vitamin D levels. Upward revision of present guidelines for vitamin D requirements and the corresponding levels of circulating 25-hydroxyvitamin D appears most needed for the frail elderly and possibly for dark-skinned persons with modest incidental or occupational sun exposure. Among the potential sources of vitamin D, nutritional supplements and more widespread fortification of certain foods, in combination with adequate calcium intake, appear to be the most desirable.

Vitamin D supplements are inexpensive, well tolerated, safe, and do not rely on season or age. On the other hand, exposure to UVB radiation in sunlight or artificial sources, such as tanning beds, carries the risk of increased photoaging and skin cancer. Given that vitamin D photosynthesis and these long-term adverse effects cannot be separated from each other, UVB from natural or artificial sources cannot be recommended as a main source of vitamin D. Moreover, for fair-skinned individuals most susceptible to photoaging and skin cancer, vitamin D photosynthesis is maximal after very modest sun exposures; extended sun exposure thus provides no potential additional benefit while distinctly increasing the likelihood of photodamage. For individuals of all complexions concerned about low vitamin D levels, taking a vitamin D supplement all year long and using proper sun protection would appear to be the ideal strategy.

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