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A Photobiological Evaluation of Tanning Booths

Abstract. *The use of tanning booths as a substitute for natural sunlight is becoming increasingly popular. However, unless careful attention is paid to proper design and maintenance, the radiation field inside a tanning booth can be highly anisotropic. The use of simple, inexpensive ultraviolet radiation meters to measure dosage can lead to serious overexposure. Since the ultraviolet radiation inside a tanning booth has a greater proportion of short wavelengths (< 300 nanometers) than natural sunlight, the amount of skin cancer–inducing radiation received for a tan may be twice that received for a natural suntan.*

Discussion of the potential health hazards of tanning booths has been mainly limited to immediate and obvious hazards such as excessive sunburn, photokeratitis of the eye, and accidents involving broken glass or electrical shock (*1*). A few dermatologists have mentioned possible long-term effects, such as wrinkling and skin cancer, but these have not been quantified. The operators of tanning salons generally claim that their tanning booths simulate sunlight and therefore pose no more long-term risks than does sunlight itself. This report examines the tanning booth from a photobiological point of view.

To provide a basis for a quantitative photobiological assessment, we made measurements in a custom-built tanning booth (*2*) in a local salon. The operator had copied the idea, booth dimensions, and equipment requirements from another salon. Although the booth we examined is not a commercial one and may not be representative of all tanning booths, the results for this booth nonetheless demonstrate many of the aspects that must be considered when evaluating the efficacy and safety of tanning booths in general.

Figure 1 gives a schematic view of the booth we examined. Two 72-inch fluorescent sunlamps in a standard "slimline" fluorescent fixture (without reflector) are mounted vertically in each of the four corners of the booth, the door and walls of which are covered with metallized wallpaper. The ultraviolet (UV) irradiances from the lamps, measured with a commercially available, commonly used UV radiation meter (*3*), are indicated.

The extreme anisotropy of the radiation field is apparently due to lack of sufficient UV reflectivity of the inner wall covering (although it visibly appeared to be a fairly good reflector) and lack of uniformity of the individual lamps (although they did not visibly appear very different). We found that the lamps ranged in age from those that were new (position 1) to those used for 2 hours (positions 5 and 7) or 24 hours (position 3). Subsequent laboratory tests on new sunlamps indicate that the UV irradiance is about 30 percent higher during the first half-hour of use than after 10 hours. After 10 hours the output changes very slowly (a loss of 0.14 percent per hour). In addition, the lamps in position 5 were found to be malfunctioning.

It is clear that unless the user stations himself in the exact center of the booth and rotates uniformly, a highly uneven tan will result—with the possibility of serious sunburn to those areas of skin closest to the lamps. (Note also that it is virtually impossible for a normal adult in this booth to remain at least 1 foot away from each lamp as recommended by the lamp manufacturer.) These problems could be ameliorated by better booth design and by burning the lamps for 10 hours before exposing the patrons to them. However, unless UV irradiance measurements are made, there is no way to ensure that the radiation field is uniform. Most tanning salons are probably not equipped to make such measurements.

We now turn to a quantitative consideration of whether a well-designed tanning booth with a uniform radiation field presents a greater long-term health risk than the sun. To evaluate this we made spectroradiometric measurements (*4*) of pairs of sunlamps under laboratory conditions. We did not attempt to duplicate tanning booth geometry because we were primarily interested in the basic spectral outputs of the lamps, uncomplicated by reflectance and multisource variables. Figure 2A shows the spectral output of two 72-inch, 55-W lamps at 33 cm, the minimum lamp-to-subject distance recommended by the manufacturer. For comparison, Fig. 2A also shows the calculated noontime spectral irradiance (*5*) from the sun at 30°N. At the shorter wavelengths, the lamps' output is significantly higher than the sun's, whereas at wavelengths greater than about 305 nm, the sun's output is higher. Thus the sunlamps do not closely simulate the sun in the UV region.

Figure 2A also shows the spectral irra-

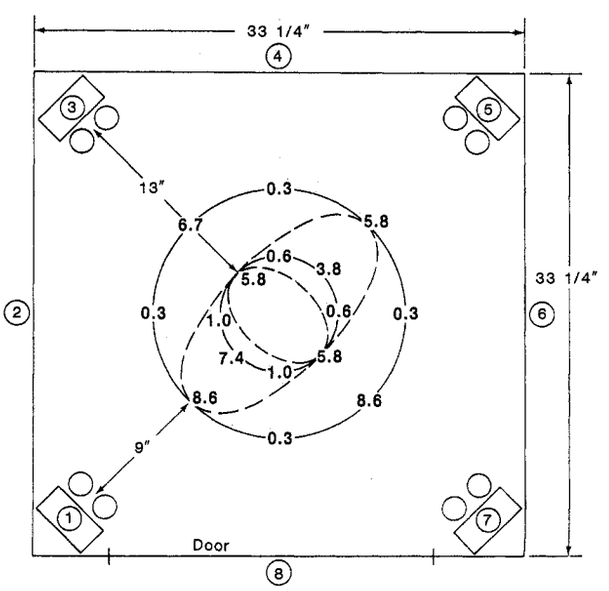

Fig. 1. Schematic view of a tanning booth. Two fluorescent sunlamps are mounted vertically at positions 1, 3, 5, and 7. The dashed ellipses represent rough cross-sectional (transverse) views of head and trunk for a typical person. Numbers indicate readings obtained with a commonly used UV radiation meter (*3*) whose sensor was pointed radially in a horizontal plane 50 inches from the floor at the locations shown. The outer circle corresponds to the position of the arms; the inner circle corresponds to the position of the head or chest.

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Table 1. Comparison of biologically effective irradiances from the sun and sunlamps.

Source	Unweighted irradiance at 270 to 360 nm (W/m^2)	Relative irradiance*		
		Weighted for erythemal effectiveness	Weighted for DNA damage	Weighted for DNA damage and skin transmission
Sun, equator†	34.5	1.31	1.51	1.41
Sun, 30°N	33.6	1.00	1.00	1.00
Sun, 40°N	31.7	0.81	0.75	0.78
Sun, 50°N	28.6	0.61	0.51	0.55
Two sunlamps, unfiltered	5.4	3.94	26.20	7.55
Two sunlamps, filtered‡	3.6	1.50	4.77	2.28

*Normalized to 1.00 for the noontime summer sun at 30°N. †Solar zenith angle, 0°; ozone thickness, 0.255 atm-cm (highest mean irradiance on earth). ‡Filtered with cellulose acetate solarized for 24 hours.

diance of two 48-inch, 40-W fluorescent sunlamps, which are used in some commercially available tanning booths. Although the UV irradiance is about one-third less than that from the 72-inch lamps, the relative spectral output is the same. Therefore, the following discussion, which is based on the results with the 72-inch lamps, is applicable to booths with lamps of either size.

Tanning is a very complex response to UV radiation. It involves both "immediate" tanning, the darkening of already synthesized melanin, and delayed tanning, the synthesis, migration, and aggregation of melanin-containing organelles (melanosomes) in the epidermis. Immediate tanning is apparent soon after exposure to UV-A radiation (320 to 400 nm) and visible light but fades in a day or so; delayed tanning is seen a few days after exposure to UV-B radiation (290 to 320 nm) and persists for several weeks (*6*).

Presumably it is the delayed tanning that is desired by persons visiting tanning parlors; however, some sunburn damage almost always accompanies the induction of such a tan (*6*). In sunburn there is both cellular injury and erythema (reddening of the skin). Although the erythema is the visible aspect, it may be relatively unimportant compared to cellular injury. However, because the cellular damage response has not been adequately quantified, we shall assume that the erythema reflects the cellular injury and tanning factors, and compare the erythemal effects of sun and sunlamps.

Not all UV wavelengths are equally effective in producing erythema or other photobiological effects. The relative erythemal effectiveness versus wavelength (the erythemal action spectrum) is shown in Fig. 2B. The curve is an analytical representation (*7*) determined by a nonlinear least-squares analysis of data from five reports (*8–12*). To compare the erythema-producing radiation from the sun with that of the lamps, the spectral irradiances presented in Fig. 2A are multiplied by the relative erythemal effectiveness at each wavelength in Fig. 2B, summed over the range 270 to 360 nm, and normalized to the erythemally weighted irradiance of the sun at 30°N (Table 1). For a given exposure time, two sunlamps at 33 cm produce 3.94 times more sunburning irradiation than the noontime summer sun at 30°N and 4.86 (3.94/0.81) times more than the noontime summer sun at 40°N. Thus, it takes about one-fifth the time to achieve a sunburn with the lamps as it does with the solar irradiance at 40°N.

Various investigators (*8–12*) have measured the energy required to produce minimally perceptible erythema (a slight pinkish appearance of the skin measured 8 hours after exposure). The minimal erythemal dose (MED) is somewhat variable. There can be as much as an order of magnitude of variation between individuals (*11*), and absolute values are dependent on the measurement technique (*13*). Averaging the results from five reports (*8–12*), we obtain an MED at 300 nm of 206 J/m^2, with a standard deviation of ± 47 percent. By using this value and the action spectrum in Fig. 2B, we calculate that 12 ± 6 and 14.5 ± 7.2 minutes of exposure are necessary to produce an MED at 30°N and 40°N, respectively. Two sunlamps at 33 cm produce an MED after only 3 ± 1.5 minutes.

It would be desirable for all tanning salon operators to use a UV radiation meter like the one we used (*3*) to test for anisotropy and to determine appropriate exposure times as lamp output declines. However, they should be warned that the meter reading, which is advertised as equivalent to MED's per hour, is calibrated only for the midday sun. When used with fluorescent sunlamps, 1 MED per hour on the meter represents 4.3 MED's of erythemally effective irradiance per hour, so exposure times should be reduced accordingly.

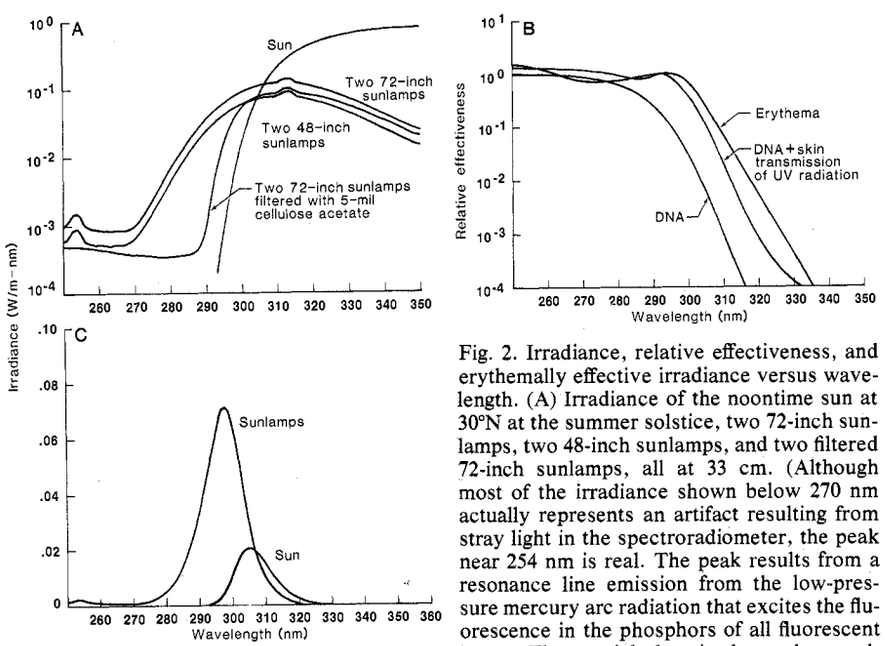

Fig. 2. Irradiance, relative effectiveness, and erythemally effective irradiance versus wavelength. (A) Irradiance of the noontime sun at 30°N at the summer solstice, two 72-inch sunlamps, two 48-inch sunlamps, and two filtered 72-inch sunlamps, all at 33 cm. (Although most of the irradiance shown below 270 nm actually represents an artifact resulting from stray light in the spectroradiometer, the peak near 254 nm is real. The peak results from a resonance line emission from the low-pressure mercury arc radiation that excites the fluorescence in the phosphors of all fluorescent lamps. The special glass in the sunlamps allows some of this radiation to escape.) (B) Relative biological effectiveness versus wavelength (action spectrum) for induction of minimal erythema in untanned Caucasian skin (*7*) and for DNA damage with and without skin transmission. (C) Irradiance weighted for erythemal effectiveness versus wavelength for the noontime sun at 30°N at the summer solstice and for two 72-inch sunlamps at 33 cm. Values were calculated by multiplying the irradiances given in (A) by the appropriate relative effectivenesses shown in (B).

The exposures required for greater degrees of erythema (and, presumably, darker tanning) cannot be readily determined. At wavelengths below about 280 nm, the erythema produced by three times the MED does not reach the same degree of redness nor last as long as that produced by three times the MED at wavelengths around 300 nm (*9*). Van der Leun (*13*) argued that the difference between the erythema produced by short wavelengths (250 to 280 nm) and that produced by wavelengths between 280 and 320 nm reflects two independent types of erythema. It is not known whether delayed tanning is associated with both types, or, if so, whether both types are equally effective. Thus, a person using a tanning booth, where a large fraction of the erythemally effective irradiance is at shorter wavelengths relative to solar irradiance at 30°N (Fig. 2C), might be exposing himself to burning rays that may not induce tanning as effectively as the somewhat longer rays associated with sun-induced erythema. Indeed, the salon operator reported that the tan obtained following sunlamp-induced erythema differs qualitatively ("orangish") from that following sun-induced erythema.

While achieving the erythema required for tanning a person is also exposing himself to skin cancer–inducing radiation. Although for humans the action spectrum for skin cancer induction is not known, for hairless mice it is very similar to that at which damage to DNA occurs (*14*). We shall assume that the DNA-damage action spectrum (*15*) is applicable to an assessment of the induction of nonmelanoma skin cancer in Caucasians and compare DNA-damaging UV radiation from the sunlamp with that from the sun. Table 1 shows that the irradiance from sunlamps at 33 cm contains about 26 times more DNA-damaging UV radiation than sunlight at 30°N. The ratio of DNA-damaging irradiance to erythemally effective irradiance is 1.00 for sunlight at 30°N. For a sunlamp it is 6.65 (26.2/3.94). Therefore, a sunlamp produces nearly seven times more DNA damage per unit of erythema than the sun.

Although the action spectrum for DNA damage is applicable to thin-skinned hairless mice, it may not be applicable to humans because some UV radiation is absorbed by the outer layers of the skin, preventing it from reaching the basal cell layer. To provide an idea of how skin transmission might affect this, Table 1 shows comparable values calculated with a weighting function comprised of the action spectrum for DNA damage and a transmission curve for untanned Caucasian epidermis (*16*). Even with this assumption, there is still 7.55 times more DNA-damaging UV radiation from sunlamps per unit time than there is from the sun at 30°N, or 1.92 (7.55/3.94) times more DNA damage per unit of erythema.

One means of ameliorating this problem would be to use cellulose acetate filters. (Because the transmission of UV radiation declines gradually during irradiation as a result of photodegradation of the filters, they would need to be changed every few days to maintain sufficient irradiance.) Cellulose acetate blocks the shorter wavelengths (Fig. 2A). For fluorescent sunlamps, a 5-mil filter reduces the erythemally effective irradiance by a factor of 2.6, so the exposure duration for an MED would be increased by a factor of 2.6. However, the filter would reduce the DNA-damaging UV radiation dose by a factor of 5.5 and the skin-transmitted, DNA-damaging dose by 3.3, so there would be a net improvement. However, even when equipped with such filters, tanning booths still cause more DNA damage per MED than the sun.

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$$E(\lambda) = 4.278 \times 10^{-4} e^{\lambda/37.65} \times (1 + e^{(\lambda-299.1)/2.354})^{-0.6724} + 1.119 e^{-(\lambda-250)^2/206.5}$$

where $E(\lambda)$ = effectiveness as a function of wavelength (λ) normalized to 1.0 at 300 nm.
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Compartmentalization of Cyclic AMP During Phagocytosis by Human Neutrophilic Granulocytes

Abstract. *Immunocytochemistry shows that early during phagocytosis of zymosan, adenosine 3',5'-monophosphate (cyclic AMP) appears on the cell surface before the phagosome is internalized. The appearance of cyclic AMP on the cell surface is coincident with that of granule products and regulatory subunit of type I cyclic AMP-dependent protein kinase. Guanosine 3',5'-monophosphate is not associated with the initiation site of phagocytosis, but is observed throughout the granular cytoplasmic region. This sharply localized accumulation of cyclic AMP may serve as a signal for the initiation of phagocytosis.*

The signal for activating the effector systems that initiate phagocytosis by neutrophils is unknown. Since the first phase of phagocytosis involves physical and chemical contact of the neutrophil plasma membrane with the object to form the phagosome, it seems possible that, as with other bulk transport processes, adenosine 3',5'-monophosphate (cyclic AMP) is synthesized at the site of contact and provides the signal for phagocytosis. Although biochemical studies have addressed this problem, the results are apparently conflicting. For example, cyclic AMP has been reported to enhance (*1*, *2*), inhibit (*3*), and have no effect on (*4*) phagocytosis. The polarity of structure of the neutrophil is crucial in terms of movement and phagocytosis. Phagocytic stimuli are confined to minute areas of the cell surface and the resulting events proceed within a limited cell volume. Hence, we used immunocytochemical

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