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Chapter 2

Reduction of the UV burden to indoor tanners through new exposure schedules: a pilot study

Reduction of the UV burden to indoor tanners through new exposure schedules: a pilot study

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Background: The development of new pigmentation (tan) in human skin after UV exposure requires several days. Once it is developed, the tan can last for weeks. Current recommendations for tanning exposure schedules in the USA (FDA Letter to Manufacturers: Policy on maximum timer interval and exposure schedule for sunlamps, August 21, 1986) allow exposures three times per week for the development of a tan, and one to two times per week for maintenance exposures. However, this policy is often interpreted in the indoor tanning industry as allowing three exposures per week on a continuous basis. We believe that the reduction of the recommended cumulative dose to indoor tanners should be explored. Two approaches for achieving this are (1) decreasing the number of exposures and (2) increasing the time interval between exposures. To explore such changes, we conducted a pilot study.

Methods: The pilot study involved three exposure schedules (evaluated on each of six subjects) that evolved throughout the course of the study. Digital photography, visual assessment and diffuse reflectance spectrometry were used to assess skin color changes. The six pilot subjects were studied for 8–18 weeks. The changes in skin color obtained through the use of the different exposure schedules were compared with changes reported by Caswell (Caswell M, The kinetics of the tanning response to tanning bed exposures, Photodermatol Photoimmunol Photomed 2000: 16: 10–14) who used schedules based on current recommendations.

Results: Two out of the three experimental schedules produced tans comparable with those reported by Caswell. In these two schedules, cumulative doses were a factor of 2–3 below doses from current schedules.

Conclusion: The UV burden to indoor tanners can be substantially reduced without compromising the cosmetic effect. These results need to be confirmed in a larger study.

Key words: indoor tanning; pigmentation; sunlamps; UV
The $L^*a^*b^*$ color coordinate system has been developed by the International Commission on Illumination (CIE) for measuring color as perceived by the human eye.

There have been reports that patrons of indoor tanning facilities often ignore the manufacturer-recommended exposure schedules (13–15). Perhaps one of the motivations here is to obtain a tan more rapidly. In this study, we evaluated the kinetics of tanning in six subjects by three different exposure schedules, using $3 \times 3$ cm areas on the subjects’ backs. Based on a study by de Winter et al. (16), which reported that DNA damage remained elevated for 3–4 days after exposure, our initial design used a minimum 3-day separation between exposures. A similar approach has also been suggested by an Australian Standards Committee (17). The exposure schedules were modified throughout the pilot study period to achieve the goals of the study, i.e. (1) development of at least one schedule that produced a tan comparable to that achieved in the Caswell study, (2) more rapid development of the tan than in the current recommended schedules, (3) exploration of whether or not the cumulative dose could be reduced compared with current practice and (4) detection of possible saturation of pigmentation.

**Methods**

**Subjects**

Six healthy human subjects were recruited from the Washington, DC metropolitan area and gave informed, written consent before enrolling in the study. After signing an informed consent document, each subject was screened by a dermatologist. There were five females and one male in the pilot study. The sex, age, and skin phototype of all enrolled subjects are listed in Table 1.

**Clinical protocol**

The volunteers filled out questionnaires about the response of their skin to sun exposure. Based on the volunteers’ responses (18), their skin phototype was determined. When responses indicated intermediate phototype, the subjects were assigned half values, e.g. 2.5 or 3.5. Only skin phototypes 2–3.5 were enrolled.

At each visit, the subjects underwent the following procedures: (1) digital and conventional photography, (2) visual assessment, (3) diffuse reflectance spectrometry measurements, and (4) UV exposure of the study areas. The subjects were exposed in a supine position under the tanning canopy with a custom-made template, defining the $3 \times 3$ cm exposed areas. The rest of the subject’s body was protected from UV exposure. The FDA Institutional Review Board approved this study (#01-026R).

**Photography**

Photographs were taken at the beginning of each visit to document the appearance of the skin over time. We used a digital camera: single-lens reflex, Nikon D1, with 28–105 mm lens (Nikon Corporation, Tokyo, Japan). This camera contains a 23.7 × 15.6 mm, 12-bit RGB CCD with 2.7 million pixels. Digital images were acquired with internal camera sharpening turned off and the following settings: focal length $= 570$ mm, aperture $= f/29$, shutter speed $= 1/80$ s, ISO $= 200$, White Balance $= \text{Flash}$ (5400 K). Illumination was provided by the Speedotron system described in Tadokoro et al. (19).

In addition, photographs were taken using Kodak Royal ASA 200 film (Eastman Kodak Company, Rochester, NY, USA) and a Canon Rebel 2000 35 mm camera with 28–80 zoom lens Canon, USA, Inc., Lake Success, NY, USA). The settings for this camera have been previously described elsewhere (19).

**Ultraviolet radiation sources and measurements**

For the tanning exposures, we used a 12-lamp tanning bed canopy (SunQuest Model SQ 2000S, ETS, Indianapolis, IN, USA) designed for home use. The canopy was equipped with 12–100 W tanning lamps that are typically used in tanning salons (Wolff Velocity, Wolff...
Systems Technology Corp., Kennesaw, GA, USA for subject T1 and Beach Sun, Light Sources, Orange, CT, USA for subjects T2 – T6). The emission spectra of all lamps used in this study were measured using a double-grating spectroradiometer (Optronic Laboratories, Model 754, Orlando, FL, USA). The spectroradiometer was calibrated with a 1000 W standard lamp that was traceable to the National Institute of Standards and Technology. A low-profile detector (SSD 001A, International Light, Newburyport, MA, USA) coupled to a radiometer (IL1700, International Light) was used before each exposure to measure the intensity in each spot on the subjects’ back and calculate the required exposure time. This detector had previously been calibrated using the measurements made with the spectroradiometer.

For the evaluation of each subject’s minimal erythema dose (MED), we used the Wolff Velocity tanning lamps for subject T1 and an array of eight Kodacel-filtered (Eastman Chemical Products, Kingsport, TN, USA) FS lamps (FSX24T12/UVB/HO, National Biological Corporation, Twinsburg, OH, USA) for subjects T2 to T6. The SSD 001A detector was used before each exposure as described above.

Minimal erythema dose determination
At the first visit (Day 1 = d1), exposures were administered on one side of the back to determine each subject’s MED. Eight 2 × 2 cm areas were exposed to arithmetically increasing doses of UV from the FS lamps. The eight administered doses were based on an assumed MED for each subject according to the following scheme: 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, 2.0, and 2.25 times the assumed MED. We used the CIE reference action spectrum for erythema (20) to calculate the administered doses. In this study, 1 J/m² effective (weighted with the CIE action spectrum) will be referred to as 1 erythemal effective unit (EEU). Although the CIE document which describes the erythemal action spectrum contains a definition for a ‘Standard Erythema Dose,’ we chose not to use that terminology here. For phototype 2, 2.5, 3 and 3.5 subjects, we assumed the MED was 200, 250, 300, and 350 EEU, respectively. The actual MED of each subject was determined by a visual assessment of the erythema in each area 24 h after exposure. We defined the MED as a pink erythema with at least one border.

Experimental tanning exposure schedules
Three 3 × 3 cm areas (A, B, C – Fig. 2) on the subject’s back were used for the tanning exposures. Area X was kept as an unexposed control. We measured the skin color in all four areas on the first visit, before the UV exposure. This value was subtracted from all subsequent measurements in each respective area.

A maximum dose of 600 EEU was selected based on the current maximum recommended dose in the FDA Policy Letter. This dose corresponds to approximately four MEDs as defined in the 1986 Policy Letter. All schedules used 100 EEU for the initial dose, as is recommended in the International Standard for ‘Safety of household and similar electrical appliances, Part 2: Particular requirements for appliances for skin exposure to ultraviolet and infrared radiation’ – IEC 60335-2-27 (21). This initial dose also corresponds to approximately 0.75 MED, the initial dose that is recommended in the FDA 1986 Policy Letter.

In the initial design, Schedule A called for one exposure per week, for 6 weeks, followed by three visits (one per week) for measurements only. Schedule B called for two exposures per week (approximately 3 days apart) for 3 weeks, then one exposure per week for the remaining 3 weeks, with three follow-up visits for measurements only. Schedule C called for two exposures per week for 4 weeks, one exposure per week for 2 weeks, and three follow-up visits for measurements only. In exposure schedules A and B, doses increased by 25% per session, up to a maximum of 600 EEU. In schedule C, doses increased by 50% and then remained stable at 600 EEU. The final exposure schedules (used for subjects T5 and T6) are provided in Table 2.

Table 2. Exposure schedules in EEU used for subjects T5 and T6

<table>
<thead>
<tr>
<th>Week</th>
<th>Day</th>
<th>Dose (EEU)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Schedule A</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
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</tr>
<tr>
<td>2</td>
<td>2</td>
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<tr>
<td>Total dose</td>
<td>1900</td>
<td>2880</td>
</tr>
</tbody>
</table>

EEU, erythemal effective unit.

Visual evaluation of changes in skin pigmentation
At each visit, the skin pigmentation or tan was evaluated by eye before that day’s UV exposure using the grading scale shown.
We measured the skin color using a Minolta CM-2002 spectrophotometer (Minolta Corporation, Ramsey, NJ, USA). The Minolta CM-2002 measures the diffuse reflectance (DR) from 400 to 700 nm at 10 nm increments using an integrating sphere with an 8 mm aperture and a target mask that minimizes pressure in the measured area. The CM-2002 was calibrated according to the manufacturer’s recommendations. At each visit, three averaged readings of spectral reflectance were taken for all four study areas. The Minolta CM-2002 uses the spectral reflectance data to calculate the $L^*$, $a^*$, and $b^*$ values. $L^*$ indicates lightness and is related to the ‘luminous reflectance’ (quantity of reflected light weighted with the spectral response of the human eye). Therefore, the lower the $L^*$ value, the darker the sample appears visually. The $a^*$ value indicates the color of an object on a scale from green for negative values to red for positive values. The $b^*$ value ranges from blue for negative values to yellow for positive values. We chose to report the change in the $L^*$ value and the vector quantity $E$ (combination of all three parameters) in this analysis in order to compare with values reported by Caswell, where

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

For each parameter, the baseline values measured on d1 are subtracted from the values measured at each subsequent visit.

## Results and discussion
### MED determination
The MED for subject T1 was determined using the Wolff Velocity tanning lamps. However, the resulting skin color had a strong brown component (possibly owing to residual immediate pigment darkening) and the visual evaluation of the MED was difficult. Thus, the MED in the remaining subjects was determined using FS lamps. The MEDs of the subjects ranged from 250 to 500 EEU and did not correlate well with skin phototype (Table 1).

### Tanning sources
Our objective was to use a tanning lamp with a proportion of UVB similar to the Wolf Bellarium S, a 5% UVB lamp that has been frequently used in tanning salons over the past few decades (22). For the first subject we used the Wolff Velocity lamp, which emits approximately 5% of its spectrum in the UVB region. However, after T1 completed the tanning protocol, we switched to the Light Sources Beach Sun lamp to shorten the exposure time. This lamp has an emission spectrum with a relatively high UVB output, similar to, but higher than the Wolff Velocity lamp. The time required to deliver 100 EEU was reduced from approximately 7 to 4 min. The emission spectra for both lamps are shown in Fig. 1.

### Doses from current schedules
For comparison purposes, the manufacturer-recommended tanning schedule used by Caswell was converted to EEU using actual measurements of the emission spectrum from his study (Robert Sayre, personal communication) and is shown in Table 3. This schedule was based on the FDA 1986 Policy Letter.
Letter (3). This policy stipulates that the maximum exposure should never exceed four MEDs of 156 J/m² (MED FDA) weighted with an erythema action spectrum that was a modified version of the then proposed CIE action spectrum for erythema. Four MEDs FDA corresponds to approximately 600 EEUs, depending on lamp spectrum. For lamps used in the Caswell study, four MEDs was equivalent to 550 EEU. The Caswell study spanned an 8-week time period, resulting in a total of 24 exposures and a cumulative dose of 9240 or 9438 EEU (depending on skin phototype).

**Progression of tan**

The progression of the tan throughout the study period is shown in Fig. 2 for one of the subjects. The final color of spot A is noticeably lighter than that of the other two spots. There is not much difference in color between spots B and C once the tan starts developing. On day 59 (37 days after spots A and B received their final exposure and 30 days after spot C received its final exposure) the pigmentation level has barely decreased, based on visual assessment.

To assess the effectiveness of different schedules, we evaluated pigmentation grade over time as shown in Fig. 3. The visual observations are shown in the upper row and the results of the instrumental measurements of ΔE and \( L^* \) are shown in the middle and lower row, respectively. The \( L^* \) values for the control area X were relatively stable during the study, except for subject T4 (see Fig. 3 legend). The \( L^* \) data show that subjects T1, T2, and T6 had a lighter constitutional skin color than subjects T3–T5. For subject T1; schedule A, with one exposure per week, was minimally effective. Therefore we increased the exposure frequency to two times per week in Schedule A for subjects T2 and T3. Subjects T2 and T3 showed markedly higher pigmentation in spot A. For subjects T5 and T6, the tanning frequency for all three exposure schedules was increased in the first week from two to three times. This shortened the time to appearance of a just perceptible tan from d10–d11 to d5–d8.

In the Caswell study, the mean change in skin color measured by ΔE ranged from 7.5 to 15 chromametric units (CU). Using a variation of three different exposure schedules, we produced ΔE values ranging from 3 to 16 CU. The schedules used for subjects T5 and T6 had ΔE values ranging from 6.5 to 16, similar to the results of Caswell.

Although no plateau was reached in each of the individual schedules, the fact that schedules B and C – with approximately a 50% difference in cumulative dose – produced very similar results indicates that the pigmentation, or the visual perception of pigmentation, tends to saturate and that further exposure is not productive, at least from a cosmetic standpoint.

Post-exposure monitoring was conducted for 2–13 weeks after the final exposure and – by visual evaluation – the tan did not diminish appreciably for at least 3 weeks post-exposure which was also noted by Sayre et al. (23) in a follow-up study of Caswell’s subjects. Therefore, after a tan is established, exposures given once every 2–3 weeks appear to be sufficient for tan maintenance.

**Assessment of erythema**

While the development of pigmentation is considered to be protective and desirable by some, er-
Erythema is considered to be undesirable and an indicator of risk. Visually, there was little to no erythema in most subjects during the exposure course. It was noted during the visual evaluation that subject T1 had slight erythema on d18 for Schedules B and C, and on d49 for Schedule C. Subject T2 exhibited mild erythema for Schedule C on d24, d28, d31, and d36.

Figure 4 shows the change in erythema over time as measured by the chromametric parameter $a^\prime$. Subjects T2 and T6 demonstrated the most significant increase in $a^\prime$ which is not surprising as they were subjects with the lowest constitutive pigmentation. They tested as skin phototype 2.5 and 2, respectively. Schedule C produced slightly more erythema than the other two schedules in all subjects, though this was not apparent for T5 till exposures ceased. This could be owing to the phenomenon reported by Alaluf et al. (24) that a higher melanin content results in a higher $a^\prime$ value. Although subjects T5 and T6 were exposed to the same schedules, they displayed marked differences in $a^\prime$ values, most likely owing to their different constitutive pigmentation. Interestingly, their MEDs were not significantly different.

In the Caswell study (11), the change in $a^\prime$ ranged from 0.5 to 8. The $\Delta a^\prime$ values from our pilot study fell within this same range. After exposures were discontinued (d31–d37) $a^\prime$ did not decrease rapidly, but tracked the drop in $\Delta E$ fairly closely. This is most likely owing to the fact that the $a^\prime$ parameter is also sensitive to an increase in melanin (24).
Conclusions
This study of three different exposure schedules in six subjects indicated that

- Sub-erythemal exposures given only once per week produce only minimal tanning (mean ΔE of 2.7 CU).
- Sub-erythemal doses given twice per week required 10–17 days for a light tan to develop.
- Increasing exposure frequency to three times per week the first week accelerated time to appearance of light tan to approximately 1 week after first exposure.
- Moderate or dark brown tans can be achieved with Schedules B and C, which prescribed maximum doses of 600 EEU and cumulative doses of 2880 and 4320 EEU, respectively. The first week of these schedules prescribed three exposures, separated by at least 48 h. The second and third weeks prescribed two exposures per week.
- Maximum pigmentation, as assessed visually and measured by $L^*$ was very similar for Schedules B and C, despite the fact that Schedule C received a 50% higher cumulative dose.
- The cumulative dose from Schedule B was a factor of three below that from current schedules that are based on the 1986 policy, yet was able to produce similar changes in pigmentation.
- The tan did not diminish appreciably for at least 3 weeks post-exposure. Therefore, after a tan is established, exposures given once every 2–3 weeks appear to be sufficient for tan maintenance.

Further studies are in progress to confirm these results in a larger number of subjects.

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