

CLINICAL ASPECTS OF THE IMMEDIATE PIGMENT DARKENING (IPD) REACTION IN NORMAL INDIVIDUALS

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Abstract. In order to investigate the clinical characteristics of the immediate pigment darkening (IPD) reaction for normal healthy Caucasian individuals and its conceivable relation to age, sex, skin type and to the minimal erythema dose (MED), a standardized light testing procedure was used and 72 subjects were studied. Skin type III was the most common, being found in 78% of the individuals; skin types II and IV were less common, found in only 12.5% and 9.5% respectively. Skin type I was not observed at all. Individuals with skin type II were found to have a significantly lower mean MED than those with skin types III and IV, and the IPD threshold dose was 9.0 J/cm² or more, which was significantly more than for skin types III and IV. The IPD reaction was absent in several individuals with skin type II under the experimental conditions used. Some differences were observed concerning the mean MED and IPD threshold doses between skin types III and IV but they were not statistically significant. Age or sex did not appear to be significantly related to the MED and IPD threshold doses observed, and, furthermore, no significant correlation, either positive or negative, was found between the MED and the IPD threshold doses when investigated for individuals with skin type III.

Key words: Standardized light testing; Normal healthy Caucasians; Skin type; Minimal erythema dose, MED; Immediate pigment darkening, IPD;

Ultraviolet irradiation may induce darkening or increased melanin pigmentation of human skin, but the degree of pigmentation obtained varies between different individuals. Two distinct tanning phenomena can be distinguished—immediate tanning or the immediate pigment darkening reaction (IPD), and the delayed tanning (DT) reaction.

The IPD reaction is induced by both long-wave ultraviolet (UVA) radiation and by visible light (4, 12, 13, 14). The phenomenon occurs without latency immediately after exposure to sufficient radiation, usually within 5 to 10 min of midday summer-sun exposure and becomes maximal after 1 h of irradiation. However, after discontinued exposure, the pigmentation so obtained gradually fades within a few hours (1, 3, 10, 11, 12, 13, 14).

The delayed tanning reaction, however, is a gradual process which involves new synthesis of melanosomes and changes in the functional state of the melanocytes and keratinocytes (5, 6, 14, 17). The DT reaction is optimally stimulated by exposure to short-wave ultraviolet radiation (UVB) and to a lesser extent by exposure to UVA and visible radiation. Maximum reaction is seen 48 to 72 h post irradiation (6, 7, 11, 14, 17).

Photochemical and micromorphological features of the IPD and DT reaction have been reviewed elsewhere (5, 6, 12, 13, 14, 15, 16, 17).

Normal individuals without any quantitative or qualitative known pathological reaction to light exposure may tolerate solar radiation quite differently depending on their skin type. Some individuals always burn initially, without subsequent pigmentation, while others almost never burn yet are easily pigmented. Furthermore, patients with a pathological light sensitivity or photodermatitis are predominantly individuals who are always and easily burned and who have poor tanning capacity prior to first appearance of photosensitivity (19).

The aim of the present study was to investigate the IPD reaction and its clinical characteristics in normal healthy individuals in relation to skin type and photodermatological parameters established by a standardized light test procedure, such as the minimal erythema dose (MED).

MATERIALS AND METHODS

Subjects

72 voluntary healthy Caucasian individuals without any known pathological reaction to solar irradiation were investigated by means of a standardized light test procedure described in detail elsewhere (18). No internal medication was allowed during the test period. The group comprised 28 men and 44 females, each sex having roughly the same age distribution, men: 39 ± 18 (range 22-76) years; females: 37 ± 11 (range 22-62).

Classification of skin type

The normal reactions to solar radiation were evaluated for all individuals. The criteria (9) were based on the history of the usual reaction to the first hour of full sun exposure in early summer in Sweden with regard to the degree of erythema and pigmentation usually obtained, and assessed according to the following type of reaction. Skin type I: always burn, never tan; II: always burn, sometimes tan; III: sometimes burn, always tan; and IV: never burn, always tan.

Light source

Light testing was performed with an Osram High Pressure Xenon arc lamp (XBO 150 W), at a distance of 15 cm from the lamp aperture to the skin (18). For MED estimations the lamp was equipped with a Schott WG 295 filter giving a sun-spectrum-like radiation (18). In order to exclude short-wave ultraviolet radiation (UVB and UVC) the lamp was equipped with a filter combination of a Schott WG 295 filter, a 3 mm ordinary glass filter and a KG 1 heat protective filter, thus providing predominantly long-wave (UVA) and visible radiation suitable for IPD provocation.

Total flux at skin level for sun-spectrum-like radiation as measured with a Hewlett-Packard radiant flux meter, was 28 mW cm^{-2} . The intensity of the lamp in the UVA region when used with the filter combination was measured primarily around the 360 nm band with a Waldmann UVA-meter (H. Waldmann Werk für Lichttechnik, Germany) and estimated to 7.5 mW cm^{-2} .

Light test procedure

Threshold doses for delayed erythema (MED) were determined in accordance with a standardized method earlier described (18) by administering a series of increasing exposures of 2-sec increments. The untanned midback was the test site. Assessment was performed 24 h after the exposure.

The IPD reaction was investigated by exposure to the lamp used with the filter combination. Continuous irradiation was administered and the time elapsed before the appearance of a significant, clearly visible, gray-brown IPD reaction was registered, from which the corresponding threshold dose was calculated. Irradiation was discontinued after a maximum dose of 9 J cm^{-2} in order to avoid any disturbance caused by a gradual increasing erythema seen for higher doses. The maximum dose used corresponds to about 45 min exposure to mid-day summer solar radiation in Sweden. The untanned gluteal region was used as test site.

No previous light exposure was allowed for at least 4 months prior to the test procedure.

RESULTS

The minimal erythema dose (MED) and the dose required to provoke the IPD reaction were estimated for all individuals and the mean value was calculated for each skin type, as seen in Table 1. Among those investigated, only skin types II, III and IV were represented.

Table 1. Minimal erythema dose (MED) and Immediate Pigment Darkening (IPD) threshold dose for different skin types (mean values \pm S.D.)

| Skin type | Number of individuals | MED (s) | IPD (J/cm^2) |
|-----------|-----------------------|----------------|-------------------------|
| II | 9 | 10.7 ± 6.2 | ≥ 9.0 |
| III | 56 | 15.3 ± 7.6 | 3.8 ± 2.3 |
| IV | 7 | 18.6 ± 4.1 | 2.8 ± 1.9 |

Individuals with skin type II showed a significantly lower MED and a significantly higher IPD threshold dose than those with skin types III and IV, but the differences seen between skin types III and IV are not statistically significant.

The mean MED value (Table I) was found to be significantly lower for individuals with skin type II when compared with those with skin type III ($p < 0.05$) and skin type IV ($p < 0.01$). The difference between skin types III and IV was not statistically significant.

There was no significant correlation between the individual's age and the MED, either for men or for women, the squared correlation coefficients (r^2) being 0.00 and 0.05 respectively. Furthermore, no significant relationship was found between sex and MED when the mean values were calculated for the largest group of test persons ($n = 56$), viz. skin type III.

The mean threshold doses for the IPD reaction was $2.8 \pm 1.9 \text{ J/cm}^2$, $3.8 \pm 2.3 \text{ J/cm}^2$ and 9.0 J/cm^2 or more, for skin types IV, III and II respectively. The difference between skin types II and III, and between II and IV, was statistically significant ($p < 0.05$ and $p < 0.01$ respectively), but not between skin types III and IV. Nine individuals had skin type II but only one showed a positive IPD reaction, seen at a threshold dose of 9 J/cm^2 coincident with the maximum dose given. Four persons were subsequently retested with higher doses, up to 16 J/cm^2 . Two of them were then positive with IPD seen for 12 and 14 J/cm^2 ; the other two individuals were still negative.

No significant correlation was found between age and the IPD threshold dose for men or women (r^2 was 0.01 and 0.24 respectively) and there was no significant difference between the mean IPD threshold dose value assessed for men and women with skin type III ($n = 56$).

Furthermore, no significant correlation, either negative or positive, was found between the individual's MED and IPD threshold dose for those

with skin type III, $r^2=0.00$ and 0.08 for men and women respectively. The mean MED was 15.3 ± 7.6 (range 6–42 s) and the mean IPD threshold dose 3.8 ± 2.3 (range 0.9–9.0 J/cm²).

DISCUSSION

In clinical experience, individuals with skin type I seem to be rare, which was confirmed in the present study of 72 normal Caucasians without any known intolerance of solar radiation. Skin types II and IV were observed in 12.5% and 9.5% respectively. Skin type III was the most frequently seen, being registered in 78%.

Individuals with skin type II are fairly sensitive to solar radiation, being easily burned and having a poor tanning capacity. In this study their mean minimal erythema dose (MED) was significantly lower than for skin types III or IV. The clinical importance of the MED reaction is not fully understood but MED is considered to be a well established parameter for the investigation and assessment of individual light sensitivity, even if the precise mechanisms underlying the reaction are still largely unknown. Current knowledge on the topic has recently been summarized and reviewed elsewhere (8, 11).

The immediate pigment darkening reaction (IPD) seems to be related to the delayed tanning capacity (DT) for different individuals (5, 6, 7, 12, 13, 14, 17). DT is most efficiently provoked by shortwave ultraviolet radiation (UVB) but erythemogenic doses are needed (6, 7, 14). IPD is provoked by longwave ultraviolet (UVA) and visible radiation (4, 12, 13, 14). IPD can be seen after fairly low doses of UVA (6, 7, 11), without any preceding erythematous reaction. Fair-skinned individuals have a low tanning capacity, with insufficient IPD and DT reactions. This investigation proved an insufficient and even absent IPD reaction in skin type II, viz. individuals reporting poor DT capacity. The IPD threshold was significantly elevated compared with skin types III and IV, and totally absent for several individuals in spite of exposures amounting 16 J/cm² (UVA).

Individual MED and IPD threshold values varied within each skin type, but no correlation, either positive or negative, was observed. Subjects with a low MED may have a low IPD threshold dose and vice versa, when calculated for the largest group of 56 individuals with skin type III. Furthermore, age

and sex was not correlated to MED or IPD in any significant degree.

MED and IPD should be considered as separate phenomena. However, MED observed for previously untanned skin in Swedish mid-day summer time amounts about 20 min of solar radiation. IPD may under similar conditions be clearly visible after 5–10 min exposure and a protective role cannot be excluded. The clinical significance of the IPD reaction may be related to acute effects. A protective role may also be claimed when long-term adverse reactions to solar radiation are considered.

Individuals with skin type II and insufficient or absent IPD should be more prone to develop pathological light sensitivity, actinic degenerative changes and cutaneous malignancies. This was documented in a previous study (19) where skin types I and II were clearly overrepresented prior to the first appearance of pathological light sensitivity. Skin types I and II were represented in 48% of patients with polymorphous light eruptions, in 42% of patients with light-sensitive psoriasis and in 57% of patients with discoid or systemic lupus erythematosus. Similarly, skin types I and II were recently found to be twice as common in patients with malignant melanoma than in controls (2).

Thus, from a theoretical point of view IPD may provide protection against ultraviolet solar radiation. This claim is supported by substantial, though indirect evidence. However, more definite clinical significance remains to be verified and further studies are required.

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REFERENCES

1. Bachem, A.: Time factors of erythema and pigmentation, produced by ultraviolet rays of different wavelengths. *J Invest Dermatol* 25: 215, 1955.
2. Beitzner, H., Ringbörg, U., Wennersten, G. & Lagerlöf, B.: The significance of light sensitivity related to skin classification in patients with malignant melanoma. Unpublished data.
3. Hausser, I.: Über spezifische Wirkungen des langwelligen ultravioletten Lichts auf die menschliche Haut. *Strahlentherapie* 62: 315, 1938.
4. Henschke, U. & Schulze, R.: Untersuchungen zum Problem der ultravioletten Dosimetrie. III. Über Pig-

- mentierung durch langwelliges Ultraviolett. *Strahlentherapie* 64: 14, 1939.
5. Jimbow, K., Pathak, M. A. & Fitzpatrick, T. B.: Effect of ultraviolet on the distribution pattern of microfilaments and microtubules and on the nucleus in human melanocytes. *Yale J Biol Med* 46: 411, 1973.
 6. Jimbow, K., Pathak, M. A., Szabo, G. & Fitzpatrick, T. B.: Ultrastructural changes in human melanocytes after ultraviolet radiation. In *Sunlight and Man* (ed. T. B. Fitzpatrick, M. A. Pathak, L. C. Harber, M. Seiji & A. Kukita), pp. 195-215. University of Tokyo Press, Tokyo, 1974.
 7. Kaidbey, K. H. & Kligman, A. M.: The acute effects of long-wave ultraviolet radiation on human skin. *J Invest Dermatol* 72: 253, 1979.
 8. Magnus, I. A.: Principles of investigating photosensitivity of the skin. In *Dermatological Photobiology*, pp. 95-116. Blackwell Scientific Publications, Oxford, 1976.
 9. Melski, J. W., Tanenbaum, L., Parrish, J. A., Fitzpatrick, T. B., Bleich, H. L. and 28 Participating Investigators: Oral methoxsalen photochemotherapy for the treatment of psoriasis: a cooperative clinical trial. *J Invest Dermatol* 68: 328, 1977.
 10. Miescher, G. & Minder, H.: Untersuchungen über die durch langwelliges Ultraviolett hervorgerufene Pigmentdunkelung. *Strahlentherapie* 66: 6, 1939.
 11. Parrish, J. A., Anderson, R. R., Urbach, F. & Pitts, D.: *UV-A. Biological Effects of Ultraviolet Radiation with Emphasis on Human Response to Longwave Ultraviolet*. Plenum Press, New York, 1978.
 12. Pathak, M. A., Riley, F. C., Fitzpatrick, T. B.: Melanogenesis in human skin following exposure to long-wave ultraviolet and visible light. *J Invest Dermatol* 39: 435, 1962.
 13. Pathak, M. A., Riley, F. C., Fitzpatrick, T. B. & Curwen, W. L. Melanin formation in human skin induced by long-wave ultraviolet and visible light. *Nature* 193: 148, 1962.
 14. Pathak, M. A.: Photobiology of melanogenesis: Biophysical aspects. In *Advances in Biology of Skin*, vol. 8 (ed. W. Montagna & F. Hu), pp. 397-420. Pergamon Press, Oxford, 1967.
 15. Pathak, M. A. & Stratton, K.: Free radicals in human skin before and after exposure to light. *Arch Biochem Biophys* 123: 468, 1968.
 16. — Effects of ultraviolet and visible radiation and the production of free radicals in skin. In *The Biologic Effects of Ultraviolet Radiation with emphasis on the skin* (ed. F. Urbach), pp. 207-222. Pergamon Press, Oxford, 1969.
 17. Pathak, M. A., Hori, Y., Szabo, G. & Fitzpatrick, T. B.: The photobiology of melanin pigmentation in human skin. In *Biology of Normal and Abnormal Melanocytes* (ed. T. Kawamura, T. B. Fitzpatrick & M. Seiji), pp. 149-167. University of Tokyo Press, Tokyo, 1971.
 18. Wennersten, G. & Swanbeck, G.: Treatment of light sensitivity with carotenoids. serum concentrations and light protection. *Acta Dermatovener (Stockholm)* 54: 491, 1974.
 19. Wennersten, G.: Carotenoid treatment for light sensitivity: A reappraisal and six year experience. *Acta Dermatovener (Stockholm)* 60: 251, 1980.

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