Acta Derm Venereol (Stockh) 1998; 78: 214–219

Interdependence of Eye and Hair Colour, Skin Type and Skin Pigmentation in a Caucasian Population

JØRGEN LOCK-ANDERSEN[1], HANS CHRISTIAN WULF[1] and NIELS DITLEV KNUDSTORP[2]

[1]Department of Dermatology, Bispebjerg Hospital, University of Copenhagen and [2]Department of Orthopaedics, Rigshospitalet, National University Hospital, Copenhagen, Denmark

Eye colour, hair colour and skin colour are important risk factors for malignant melanoma and non-melanoma skin cancers. There are few studies in which the distribution of these pigmentary factors in risk populations has been assessed. The purpose of this study was to investigate the prevalence of the major eye and hair colours and the distribution of skin types and skin pigmentation in a Caucasian population. In 892 Danish Caucasians, eye colour, hair colour and skin type were assessed and facultative and constitutive skin pigmentation were measured objectively using skin reflectance spectroscopy. Blue eye colour and blond hair colour and skin type II were the most frequent (60%, 67% and 33% of subjects, respectively). All four major eye colours and four major hair colours (with the exception of red hair colour) were found within skin types I–IV and we could not predict the skin type or the constitutive skin pigmentation. Skin type could not be taken to classify individuals reliably according to their facultative or constitutive skin pigmentation. ***Key words: epidemiology; risk factor; skin reflectance.***

(Accepted December 8, 1997.)

Acta Derm Venereol (Stockh) 1998; 78: 214–219.

Jørgen Lock-Andersen, Department of Dermatology D92, Bispebjerg Hospital, Bispebjerg Bakke 23, DK-2400 Copenhagen NV, Denmark.

Persons of fair complexion, e.g. with blond or red hair and blue eyes and lightly pigmented skin, are clinically more prone to be sunburned and to develop sun-induced skin damage. In some phototest studies the phenotypic characteristics eye colour and hair colour have been found to be related to skin type and to minimal erythema dose (MED) (1–3). The incidence of skin cancer, cutaneous malignant melanoma (CMM), basal cell carcinoma (BCC) and squamous cell carcinoma (SCC), is increasing in white-skinned populations worldwide and skin cancer is now becoming a major health problem. The fair skinned Caucasians in Scandinavia are at considerable risk of skin cancer and the CMM incidence rates are higher in Scandinavians than in populations from southern Europe (4). It has been calculated that, given the current incidence rates, 1 in every 100 Danish males and 1 in every 80 Danish females will develop a CMM during their lifetime (5).

In analytic studies of skin cancer it has been found that the phenotypic traits eye colour and hair colour and skin type and skin colour are major risk factors for CMM (6, 7), BCC (8–10) and SCC (8, 9, 11). In a meta-analysis of 10 case-control studies of CMM with more than 3,000 cases and almost 4,000 controls the odds ratio (OR) for blue eyes compared to brown eyes was calculated to be 1.6 and for red hair colour and blond hair colour compared to black or brown colours the ORs were 2.4 and 1.8, respectively (6). In a multicentre study on BCC and SCC from southern Europe, involving 1,549 BCC cases, 228 SCC cases and 1,795 controls, pale eye colour compared to dark eye colour had an OR of 1.4 for BCC and 1.8 for SCC, and red hair colour compared to black hair colour held an OR of 2.4 for BCC and 18.0 for SCC (9). Univariate estimations of OR without adjusting for exposure may be to underestimate the OR in sun-sensitive persons because these individuals probably expose themselves less to the sun than more sun-resistant persons.

In most brown-skinned and black-skinned populations there is little variation in hair and eye colour, but in Caucasians a great diversity of hair and eye colours is seen in connection with various degrees of skin pigmentation. Despite eye colour and hair colour being well-defined risk factors for melanoma and non-melanoma skin cancers, and are readily observable characteristics, surprisingly few studies assess the distribution of these pigmentary traits in Caucasian risk populations and the association of these pigmentary traits to skin type and to skin pigmentation.

The purposes of the present study were (i) to establish the distribution of hair colour and eye colour and skin type and skin pigmentation in a Danish Caucasian population, which has a high risk for development of melanoma and non-melanoma skin cancers and (ii) to investigate whether eye colour and hair colour are true predictors of skin type and skin pigmentation.

SUBJECTS AND METHODS

The population sample consisted of patients and relatives attending the outpatient clinic of the Department of Orthopaedics at the National University Hospital in Copenhagen. This clinic was chosen because persons of all ages and from a wide geographic area, including urban and rural areas, attended the clinic and because we assumed that pigmentary traits such as eye and hair colour and skin type would be unrelated to clinic attendance. In the study period, February to April 1995, approximately 1,000 persons were approached randomly by one of two trained interviewers in the clinic's waiting area and invited to participate in the study. We wanted the study to be a Danish population study and therefore excluded persons not holding Danish citizenship. Of those approached, approximately 10% declined to participate for various reasons. The study was approved by the local Ethics Committee and all participants gave informed consent before entering. Eight-hundred-and-ninety-two persons were included (518 females and 374 males), with a mean age of 37 years (SD = 18 years; range 0–85 years). Seven persons (0.8%) stated that they had previously had a skin cancer or might have had a skin cancer. Since such information is doubtful, and we could not verify this, they were not excluded.

Study design

Study subjects were interviewed in a special study room in accordance with a standardized questionnaire on age, area of living, use of artificial tanning devices, hair colour and skin type. Eye colour was assessed and skin pigmentation was measured objectively at UV-exposed sites and in

 ISSN 0001-5555

Table I. *Distribution of eye colour, hair colour and skin type*

Pigmentary trait	Study sample			Subgroup
	Males, %	Females, %	M + F, %	M + F, %
Eye colour[A]				
Blue	64.4	56.0	59.6	61.6
Green	14.2	20.1	17.6	15.1
Grey	6.3	6.0	6.1	5.5
Brown	13.7	17.9	16.1	16.8
NA	1.4	0.0	0.6	1.0
Hair colour[B]				
Red	3.2	3.9	3.6	3.5
Blond	68.0	66.8	67.3	66.6
Brown	23.8	27.5	26.0	25.4
Black	4.6	1.8	3.0	4.2
NA	0.4	0.0	0.1	0.3
Skin type[C]				
I	21.0	24.7	23.1	24.9
II	32.8	33.9	33.4	29.0
III	19.0	15.8	17.2	16.1
IV	26.3	22.8	24.3	27.9
V	0.6	1.0	0.8	0.8
NA	0.3	1.8	1.2	1.3

A subgroup of 414 persons, with an age and gender distribution as in the Danish population, was constructed from the total sample of 892 persons. [A]Eye colour assessed in study persons older than 1 year of age (study sample: $n = 868$; subgroup: $n = 398$). [B]Hair colour at 25 years of age (study sample: $n = 667$; subgroup: n = 287). [C]Skin type in persons older than 5 years of age; in children indicated by their parents (study sample: $n = 856$; subgroup: $n = 390$). M = males; F = females; NA = not available.

UV-shielded buttock skin. At the end of the examination study persons were given general advice on the risk known to be associated with excessive sun exposure and on sun protection. The interview and the pigmentation measurements took approximately 20 min for each person. The standardized questionnaire was pretested prior to the study, and during the study the two interviewers at regular intervals overheard each other's interview to ensure that interviews were being performed consistently during the study period. Before starting the study and at regular intervals during the study the two interviewers performed simultaneous assessments of eye colour in the same study persons to ensure that eye colour assessment was uniform.

Eye and hair colour

Study persons were asked to indicate their natural (un-dyed) hair colour at 25 years of age in accordance with a 5-point scale: red, light blond, dark blond, brown or black. Eye colour (colour of the iris) was assessed by the interviewers on a 4-point scale: blue, green, grey or brown. We did not assess eye colour in infants younger than one year of age because we considered eye colour to be too unstable before this age.

Skin type

The skin phototype of the participants (anamnestic recall of burning tendency and tanning ability) was estimated using the Fitzpatrick classification (12) based on a person's memory of their reaction to 2 h of sun on a sunny day at noon at the beginning of the summer period. This exposure in Denmark (situated at 56° latitude N) corresponds to a UV dose of 9 SED (one SED = 100 J/m^2/298 nm, CIE erythema action spectrum (13)). The following six skin types were available; skin type I: always burn, never tan; skin type II: usually burn, tan less than average; skin type III: sometimes mild burn, tan about average; skin type IV: rarely burn, tan more than average; skin type V: brown-skinned persons, and skin type VI: black-skinned persons. In children, the skin type was indicated by their parents but we did not estimate skin type in persons younger than 6 years because we consider anamnestic skin typing to be too uncertain or impossible before this age.

Skin pigmentation

To objectively measure the skin pigmentation we used a portable skin reflectance spectroscope (PBI UV-Optimize, Model 550/660, PBI Medical, Ringsted, Denmark) which utilizes wavebands of visible light at 555 and 660 nm to independently measure the skin pigmentation (the melanin content) and the skin redness (the haemoglobin content) and gives the results on continuous scales from 0 to 100% (14). Zero percent pigmentation corresponds to skin with no pigmentation at all, as in an extremely white person; 100% pigmentation corresponds to no light reflected back, as in theoretical absolutely black skin. The resolution of the pigmentation scale and precision of the instrument allows for at least 40 steps for measurements of skin pigmentation in European Caucasians (15). The measuring probe is held lightly against the skin and after a few seconds the readings, which are the average of three independent measurements, are given on the display. Before each measurement session the apparatus was calibrated on a white reference tile. Pigmentation measurements were performed at UV-exposed sites: on the forehead; on the upper chest in the infraclavicular region; on the upper back in the suprascapular region; at the lateral aspect of the upper arm 7 cm above the lateral epicondyle; at the medial aspect of the upper arm 7 cm above the medial epicondyle, and at the UV-shielded site of the medial and upper quadrant of the buttocks. The study period of February to April was carefully selected because the effect of seasonal variation on facultative skin pigmentation is least during these months of the year (16).

Statistics

The distribution of age and gender in the study sample was compared using the Chi-squared test to the expected distribution calculated from the Danish population as recorded by January 1996 (17). Analysis of eye colour, hair colour and skin type by gender was performed using the Chi-squared test, and skin pigmentation by gender was analysed using the unpaired *t*-test. Skin pigmentation according to skin types was analysed using the Mann-Whitney test. We considered p values less than 0.05 to be significant.

RESULTS

Study sample versus the Danish population

As expected, the majority of study persons came from the Copenhagen area, with 48% from the central part of Copenhagen (Copenhagen municipality; population January 1996: 476.751 persons (17)), but all of the 14 Danish counties were represented in the study sample. The observed age and sex distribution of the study sample was compared with the expected age and sex distribution calculated from the Danish population distribution in 1995 and was found to be different ($p < 0.01$) due to too few persons older than 59 years (approximately 50% of the expected number) and too many women in the age group 20–59 years (approximately 160% of the expected number). From the total sample of 892 persons a subgroup of 414 persons was selected (204 males and 210 females) with a similar age and sex distribution as in the Danish population by random reduction of persons in overrepresented age-gender groups. In this subgroup the distribution of eye and hair colour and skin type was also extracted (Table I). Compared to the total sample, only minor differences were found for the distri-

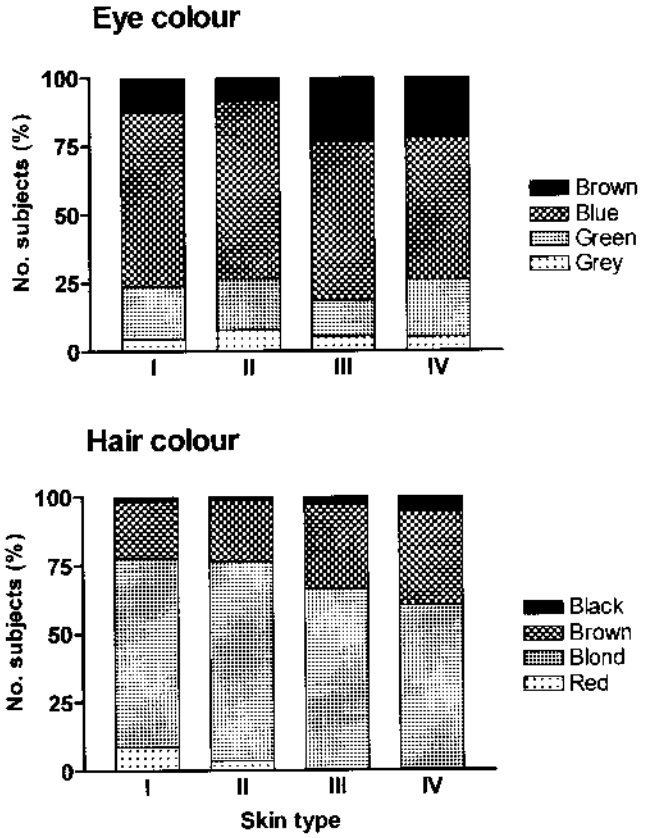

Fig. 1. Eye colour and hair colour according to anamnestic skin type. Eye colour in 868 persons older than 1 year of age and hair colour at 25 years of age in 667 persons.

bution of eye and hair colour and skin types in the age and gender population comparable subgroup (Table I).

Eye colour

The dominating eye colour in the sample was blue with the fair eye colours (blue, green and grey) constituting the majority in both males and females; only 16% had brown eye colour (Table I). There was a gender difference with more males having blue eye colour and more females having brown eye colour ($p=0.03$). All four eye colours were found in skin types I–IV (Fig. 1) and even brown eye colour was found in 13% of persons with skin type I. There was no obvious trend for any eye colour to be associated with a particular skin type. When eye colour was compared to objective measurements of constitutive skin pigmentation at the buttocks we also found all four eye colours within the four groups of pigmentation (Fig. 2), but with a slight tendency for brown eye colour to be more associated with darker pigmented skin. Eye colour was therefore found to be an unreliable predictor of anamnestic skin type and of constitutive skin pigmentation.

Hair colour

Only 4% of the sample of Caucasians had red hair colour at the age of 25 years and only 3% had black hair colour (Table I), with blonds (light blond and dark blond) being the dominating colours and with no statistical gender difference ($p=0.15$). All hair colours were found in the four skin types I–IV except red hair, which was only found in skin types I and II (Fig. 1). There was a tendency for brown and black hair colour to be associated with the more sun-resistant skin types III and IV and with a higher degree of constitutive skin pigmentation (Fig. 2), while blond and red hair were more associated with the sun-sensitive skin types I and II and to lesser levels of constitutive pigmentation. However, these were only weak trends and overall hair colour was not found to be a predictor of skin type or of the degree of constitutive skin pigmentation.

Skin type and skin pigmentation

Skin type II was the dominant skin type found in 33% of the study persons (Table I), but a surprising 24% indicated skin type IV. There was no gender difference in the distribution of skin types ($p=0.41$). Facultative skin pigmentation at UV-exposed sites was higher in females than in males except for the forehead (Table II). Buttock skin pigmentation was also statistically higher in females, but when solarium users were excluded there was no significant difference between constitutive skin pigmentation at the buttocks in either females or males (13.3 vs. 12.8, $p=0.18$). More females than males were solarium users (33% of females and 14% of males). Considering only persons that were not solarium users, females still had sig-

Table II. *Skin pigmentation at various body sites*

Body site	Males			Females		M+F	
	mean	SD		mean	SD	mean	SD
Upper arm, lateral	23.9	5.4	$p=0.02$	24.8	5.6	24.5	5.5
Chest	19.9	5.9	$p<0.01$	22.1	5.9	21.1	6.0
Back	19.8	5.5	$p<0.01$	21.2	5.6	20.6	5.6
Upper arm, medial	18.9	4.5	$p<0.01$	22.1	5.0	20.7	5.0
Forehead	18.1	5.4	$p=0.39$	17.8	5.0	17.9	5.2
Buttock[A]	13.3	5.5	$p<0.01$	14.8	5.6	14.2	5.6
Buttock[B]	12.8	4.8	$p=0.18$	13.3	4.8	13.1	4.8

Skin pigmentation measured by skin reflectance spectroscopy at UV-exposed skin sites in all persons (facultative pigmentation) and at buttock skin in all persons[A] ($n=889$) and in buttock skin of persons[B] not using artificial tanning devices ($n=666$). Only in persons not using artificial tanning devices can the buttock pigmentation be considered to be the constitutive pigmentation. Statistical analyses of gender differences by the unpaired *t*-test.

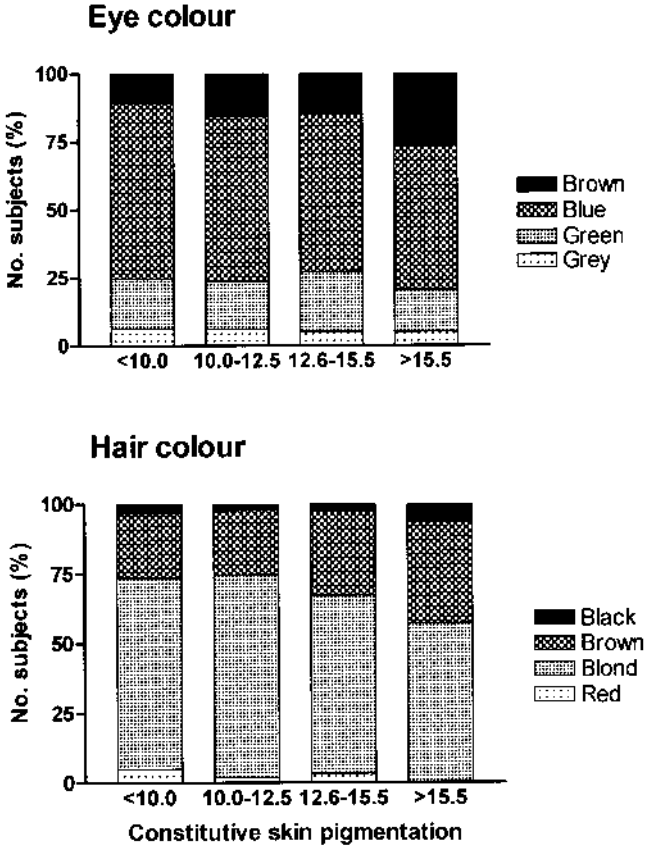

Fig. 2. Eye colour and hair colour according to constitutive skin pigmentation. Eye colour in 619 persons (older than 1 year of age) and hair colour at 25 years of age in 506 persons according to constitutive skin pigmentation measured by skin reflectance spectroscopy in persons not using artificial tanning devices. The four pigmentation quartiles divided the persons into four pigmentation groups (median buttock skin pigmentation = 12.5% pigment).

nificantly higher pigmentation at the chest and at the inside of the upper arm ($p < 0.01$ for both regions), while pigmentation at the forehead, the back and the outside of the upper arm did not differ statistically in females and males. Fig. 3 shows objectively measured skin pigmentation according to subjectively assessed skin type for the lateral arm and the back and buttocks. For the arm there were significant differences in pigmentation between adjacent skin types but for the back and the buttocks there were no significant differences between pigment distribution in adjacent skin types except for skin types II and III. The box-and-whisker plots demonstrate that there is considerable overlapping in pigmentation range for all skin types and that anamnestic skin cannot be used as an indicator to clearly distinguish between different degrees of facultative and constitutive skin pigmentation in individual subjects.

DISCUSSION

In this study, we have used simple but clinically relevant colour scales to assess eye colour and hair colour rather than elaborate artificial scales which are of doubtful clinical relevance. For assessing skin pigmentation we benefited from having skin reflectance spectroscopy equipment giving objective pigmentation measurements on a continuous scale rather than artificial skin colour scales which at best have a resolution of seven steps in Caucasians (15). Furthermore, we have previously established that measurements of skin pigmentation by reflectance spectroscopy in not-previously UV-exposed buttock skin will predict the UV sensitivity, as determined by a MED phototest, with a high degree of precision (18).

Anamnestic skin type is per definition dependent on the recall precision of the study person's memory and cannot be objectively estimated. Furthermore, skin typing involves the combination of two different questions: burning susceptibility and tanning ability. This is unfortunate from a scientific point of view with only four possible combinations of burning tendency and tanning ability and may force Caucasians into choosing a wrong skin type because the right combination of burning tendency and tanning ability is not available (19). Moreover, the questions used in skin typing may be interpreted differently in different populations and cultures. Despite this obvious weakness, skin typing has found widespread use in clinical and epidemiological studies because it is quick and easy and can be performed without any equipment.

We found that the major eye colour in the Danish population was blue, which compares well with the study of Pálsson et al. (20). Females had darker eye colours than males, which has also been found in other studies (21). Eye colour is not static, however, and in a longitudinal study in children from 3 months to 6 years of age Matheney & Dolan (21) have found an age trend with a decrease in the lighter eye colours and a corresponding increase in the darker colours with age. In parallel with age-associated changes in eye colour it has been shown that the hair of Caucasians tends to darken with age (22). We chose to look at hair colour at the age of 25 years to avoid this age-related trend because our study sample had a wide age range from 0 to 85 years.

In a study in 809 indoor office workers by M. Berg performed in four Swedish cities (23), it was found that the most frequent skin type was type III, with 61% of the study persons; the least represented was skin type I, with only 2% . The greatest variation in skin types between the four cities in the Swedish study was in skin type IV, with 4% of the study persons in Gothenburg in the south region of Sweden and 16% in Sundswall in the northern region (23). In the German skin cancer screening campaign "Give Skin Cancer No Chance" (24) it was found that approximately 84% of the 24,432 screened persons were of skin type II or III.

We found that eye and hair colours were evenly distributed within almost all skin types and Hoffman et al. (24) found a comparable distribution of hair and eye colours within the four Caucasian skin types. Eye and hair colour cannot therefore be used as a substitute for skin typing in studies of sun sensitivity. However, eye and hair colour seem to carry additional information about sun reactivity which is not contained in the Fitzpatrick classification. These two pigmentary traits have been shown to be independent risk factors of skin cancer after adjustment for skin type (6, 9) and should therefore be included in analytic studies of skin cancer aetiology.

Our objective measurements of facultative and constitutive skin pigmentation in all skin types showed a considerable darkening of the skin at UV-exposed sites compared to non-UV-exposed buttock skin. Females had more pigmented skin at the exposed sites (Table II) but not at UV-unexposed buttock skin, suggesting that females had been more UV-exposed than males. The four major eye and hair colours were found within

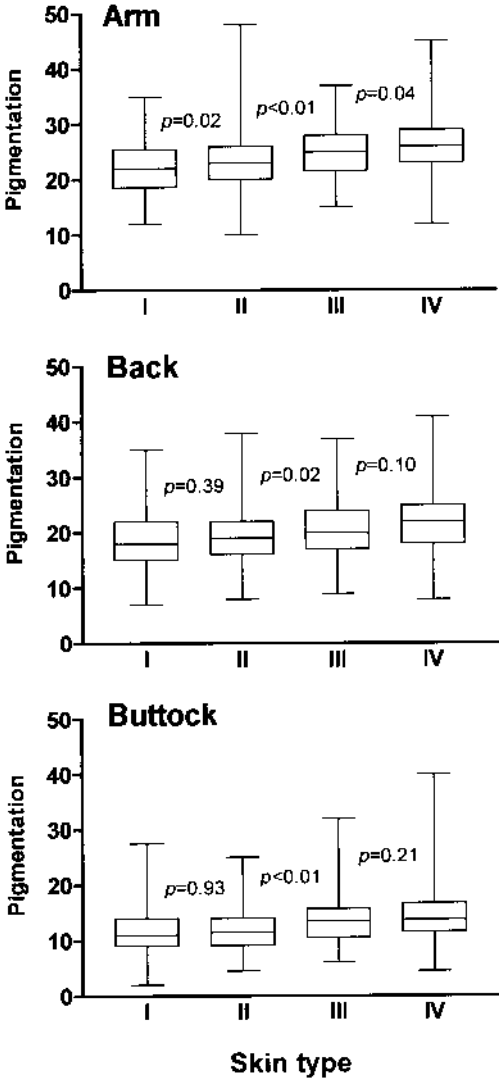

Fig. 3. Objectively measured skin pigmentation in UV-exposed and unexposed skin. Facultative skin pigmentation in persons not using artificial tanning devices at the outside of the upper arm (668 persons) and the upper back (667 persons) and the medial and upper quadrant of the buttocks (666 persons) according to their anamnestic skin type. Data are shown as box-and-whisker diagrams where the box extends from the 25th percentile to the 75th percentile and with a horizontal line at the median value (50th percentile). Whiskers extend down to the minumum value and up to the maximum value. Note the extensive overlapping in range of skin pigmentation between all skin types, not just for the extreme pigmentation values but also for the main core of values (25th percentile to 75th percentile) in all skin types. Statistical analysis of skin pigmentation in skin type I vs. type II, type II vs. type III, and type III vs. type IV by Mann-Whitney's test.

all four pigmentation groups (Fig. 2) except red hair colour, which was not found in the most pigmented group. Hair colour and eye colour and skin pigmentation are regulated by different genes by complex genetics (25–28) and may result in a wide variety of phenotypes. There are two different types of melanin present in human hair [the brownish black eumelanin and the reddish yellow pheomelanin (29)] which differ not only chemically but also physically (30). Recent studies have now demonstrated the presence of pheomelanin in human skin (31) and there seems to be an association between the two melanine types in hair and skin (31, 32).

Fig. 3, which correlates skin types to skin pigmentation, demonstrates clearly that Fitzpatrick skin types in Caucasians cannot reliably be used to classify individual subjects according to their constitutive skin pigmentation, since persons with a broad range of constitutive pigmentation are found within each skin type and there is wide overlapping between adjacent skin types. This is in accordance with our previous results on UV sensitivity in 248 persons of skin types I–V (15) and other phototest studies (19, 33). We have even found that reproducibility of anamnestic skin type is quite unsatisfactory because one of every three persons could not classify themselves in the same skin type 6 to 12 months after first being questioned (15). These observations stress the need for a new skin type classification system.

ACKNOWLEDGEMENTS

We thank Mariane Bauer for invaluable help with data collection and Age Vølund for help with data analysis. The study was supported by a grant from the Danish Cancer Society (Grant No. 94–037).

REFERENCES

1. Amblard P, Beani J, Gautron R, Reymond J, Doyon B. Statistical study of individual variations in sunburn sensitivity in 303 volunteers without photodermatosis. Arch Dermatol Res 1982; 274: 195–206.
2. Andreassi L, Simoni S, Fiorini P, Fimiani M. Phenotypic characters related to skin type and minimal erythemal dose. Photodermatol 1987; 4: 43–46.
3. Azizi E, Lusky A, Kushelevsky AP, Schewach-Millet M. Skin type, hair color, and freckles are predictors of decreased minimal erythema ultraviolet dose. J Am Acad Dermatol 1988; 19: 32–38.
4. Østerlind A. Epidemiology of malignant melanoma in Europe. Reviews in Oncologica 1992; 5: 903–908.
5. Østerlind A. Defining individual risk factors for skin melanoma. In: Altmeyer P, Hoffmann K, Stücker M, eds. Skin cancer and UV radiation. Berlin: Springer Verlag, 1997: 562–570.
6. Bliss JM, Ford D, Swerdlow AJ, Armstrong BK, Cristofolini M, Elwood JM, et al. Risk of cutaneous melanoma associated with pigmentation characteristics and freckling: systematic overview of 10 case-control studies: the International Melanoma Analysis Group (IMAGE). Int J Cancer 1995; 62: 367–376.
7. Evans RD, Kopf AW, Lew RA, Rigel DS, Bart RS, Friedman RJ, et al. Risk factors for development of malignant melanoma–I: review of case-control studies. J Dermatol Surg Oncol 1988; 14: 393–408.
8. Suárez-Varela MM, González AL, Caraco EF. Non-melanoma skin cancer: an evaluation of risk in terms of ultraviolet exposure. Eur J Epidemiol 1992; 8: 838–844.
9. Zanetti R, Rosso S, Martinez C, Navarro C, Schraub S, Sancho-Garnier S, et al. The multicentre south European study "Helios". I: Skin characteristics and sunburns in basal cell and squamous cell carcinomas of the skin. Br J Cancer 1996; 73: 1440–1446.
10. Gallagher RP, Hill GB, Bajdik CD, Fincham S, Coldman AJ, McLean DI, et al. Sunlight exposure, pigmentary factors, and risk of nonmelanocytic skin cancer. I. Basal cell carcinoma. Arch Dermatol 1995; 131: 157–163.
11. Gallagher RP, Hill GB, Bajdik CD, Coldman AJ, Fincham S, McLean DI, et al. Sunlight exposure, pigmentation factors, and risk of nonmelanocytic skin cancer. II. Squamous cell carcinoma. Arch Dermatol 1995; 131: 164–169.
12. Fitzpatrick TB. The validity and practicality of sun-reactive skin type I through VI (Editorial). Arch Dermatol 1988; 124: 869–871.

13. Wulf HC, Lock-Andersen J. Standard erythema dose. Skin Res Tech 1996; 4: 192.
14. Wulf HC. Method and apparatus for determining an individual's ability to stand exposure to UV. US Patent 1986; 14: 882, 598: 1–32.
15. Wulf HC, Lock-Andersen J. Measurements of constitutive skin phototypes. In: Altmeyer P, Hoffmann K, Stücker M, eds. Skin cancer and UV radiation. Berlin: Springer Verlag, 1997: 169–180.
16. Lock-Andersen J, Wulf HC. Seasonal variation of skin pigmentation. Acta Derm Venereol (Stockh) 1997; 77: 219–221.
17. Amternes folketal efter køn og alder. Tabel 48. In: Statistisk Årbog 1996. Danmarks Statistik. København, 1996: 69.
18. Lock-Andersen J, Gniadecka M, de Fine Olivarius F, Dahlstrøm K, Wulf HC. UV induced erythema evaluated 24h post-exposure by skin reflectance and laser Doppler flowmetry is identical in healthy persons and patients with cutaneous malignant melanoma and basal cell cancer. J Photochem Photobiol (B) 1997; 41: 30–35.
19. Rampen FHJ, Fleuren BAM, de Boo TM, Lemmens WAJG. Unreliability of self-reported burning tendency and tanning ability. Arch Dermatol 1988; 124: 885–888.
20. Pálsson JÓP, Eriksson AW, Forsius H, Fellman J. Comparison of hair and iris pigmentation in Scandinavian populations. Arctic Med Res 1994; 53: 52.
21. Matheny AP, Dolan AB. Changes in eye colour during early childhood: sex and genetic differences. Ann Hum Biol 1975; 2: 191–196.
22. Matheny AP, Dolan AB. Sex and genetic differences in hair colour changes during early childhood. Am J Phys Anthropol 1975; 42: 53–56.
23. Berg M. Epidemiological studies of the influence of sunlight on the skin. Photodermatology 1989; 6: 80–84.
24. Hoffmann K, Gebler A, Trampisch HJ, Hoffmann A, Lueg A, Altmeyer P, et al. Do not give skin cancer a chance. In: Altmeyer P, Hoffmann K, Stücker M, eds. Skin cancer and UV radiation. Berlin: Springer Verlag, 1997: 820–849.
25. Kalla AK. Human skin pigmentation, its genetics and variation. Humangenetik 1974; 21: 289–300.
26. Eiberg H, Mohr J. Major genes of eye color and hair color linked to LU and SE. Clin Genet 1987; 31: 186–191.
27. Eiberg H, Mohr J. Major locus for red hair color linked to MNS blood groups on chromosome 4. Clin Genet 1987; 32: 125–128.
28. Robins AH. Biology of the pigment cell. In: Robins AH, ed. Biological perspectives on human pigmentation. Cambridge: Cambridge University Press, 1991: 1–24.
29. Jimbow K, Ishida O, Ito S, Hori Y, Witkop CJ, King RA. Combined chemical and electron microscopic studies of pheomelanosomes in human red hair. J Invest Dermatol 1983; 81: 506–511.
30. Chedekel MR. Photochemistry and photobiology of epidermal melanins. Photochem Photobiol 1982; 35: 881–885.
31. Thody AJ, Higgins EM, Wakamatsu K, Ito S, Burchill SA, Marks JM. Pheomelanin as well as eumelanin is present in human epidermis. J Invest Dermatol 1991; 97: 340–344.
32. Valverde P, Healy E, Jackson I, Rees JL, Thody AJ. Variants of the melanocyte-stimulating hormone receptor gene are associated with red hair and fair skin in humans. Nat Genet 1995; 11: 328–330.
33. Snellman E, Jansén CT, Leszynski K, Visuri R, Milan T, Jokela K. Ultraviolet erythema sensitivity in anamnestic (I–IV) and phototested (1–4) Caucasian skin phototypes: the need for a new classification system. Photochem Photobiol 1995; 62: 769–772.