British Journal of Dermatology (1990) 123, 77–84.

Measurement and perception of skin colour in a skin cancer survey

ADÈLE GREEN AND N.G.MARTIN

Queensland Institute of Medical Research, Brisbane, Australia

Accepted for publication 8 January 1990

SUMMARY

A population-based prevalence survey of skin cancer was conducted in Nambour, Queensland, in 1986. The skin colour of 807 participants was assessed in three ways: quantitatively, graded by a dermatologist, and self-reported. Quantitation of skin pigmentation was obtained by measuring the reflectance of light of wavelength 650 nm, at six sites. Females showed higher mean reflectance (paler skin) than males at all sites with the greatest difference on the lateral forearms. Prevalent skin cancer in males, and solar keratoses in both sexes were correlated with inherently pale skin colour on an unexposed site, and the presence of keratoses was correlated with darkly-pigmented backs of the hands ($P < 0.001$). Both dermatologists' and participants' grading of skin colour were moderately correlated with measured skin colour. For dermatologists, correlation was highest with reflectance from the medial upper arms ($r = 0.35$, right arm; 0.30, left) in males, and the lateral forearms ($r = 0.34$, right; 0.38, left) in females. Correlations between reflectance values and self-reported innate skin colour were highest for the upper arms ($r = 0.26$, right; 0.24, left) in males, and for forearms ($r = 0.42$, right and left) in females. Prevalence of actinic lesions was more highly correlated with subjectively assessed skin colour than with quantitative skin pigmentation.

Skin colour is a major determinant of melanoma and non-melanoma skin cancer, yet the problem of accurately measuring skin colour has rarely been considered in studies of skin malignancy. Modern investigators[1–5] tend to rely upon a subjective grading of skin pigmentation e.g., fair, medium, olive or black, although the validity and reliability of judging skin colour are largely unknown.

Edwards and Duntley[6] first quantified skin colour 50 years ago by measuring visible light reflectance of the skin with a spectrophotometer. While reflectance measures have been used subsequently in a range of anthropological and genetic studies,[7–11] few epidemiological studies of skin cancer have used objective means of estimating degree of pigmentation. Although in two case-control studies of cutaneous melanoma[12,13] investigators estimated skin reflectance, final

Correspondence: Dr A.Green, Queensland Institute of Medical Research, Bramston Terrace, Herston, Queensland 4006, Australia.

values were obtained indirectly, so evaluation was still partly subjective. In a study of melanoma in British Columbia, observer perception of skin colour was assessed.[13] Six observers each evaluated the skin colour of eight subjects under three lighting conditions (daylight, fluorescent and incandescent light sources), and skin tones were transformed to reflectance values measured at four wavelengths. At 400–600 nm, approximately 30% of the variance was due to observers, light source, time of observation and error, but these factors accounted for 75% of the variance at wavelengths of 700 nm.[13]

During a community survey of skin cancer we measured the skin colour of 807 subjects by reflectance spectrophotometry. Also, dermatologists rated skin colour on a four-point scale, and subjects rated their own skin colour on the same scale. In this paper the relation between quantitative skin colour and prevalence of skin cancer is investigated, and objective skin-colour measurement is compared with the subjective assessment of skin colour by dermatologists, and with self-reported skin colour.

METHODS

A population-based survey of skin cancer was conducted in Nambour, Queensland, in December, 1986. Full details have been reported previously.[14] A random sample of 3000 was chosen from the 5100 residents aged 20–69 years who were enrolled in the Nambour state electorate (voter registration is compulsory in Australia). A total of 2095 people took part, with a response rate among permanent residents of 78%. Information obtained during a standard interview included: patterns of occupational and recreational sun exposure which participants classified overall as 'mainly outdoor', 'both indoor and outdoor' or 'mainly indoor' (variable labels, OCCEXP and RECEXP); acute reaction of untanned skin to strong sun, classified as 'always burn, never tan', 'burn then tan' or 'only tan' (BURNTAN); number of painful sunburns in life (SUNBURN); and past history of skin cancer (PREVSKCA). Each person was also asked, 'How would you rate your natural skin colour on areas never exposed to the sun (like under your arm): fair, medium, olive or black?' (SKCLSELF). Response categories for all items are shown in Table 1.

Every subject was examined by one of 14 dermatologists. In 90% of subjects, only the head and neck, backs of hands and forearms were inspected, while a random 10% of subjects received a full skin examination. The dermatologists assessed natural skin colour (SKCLDERM), eye and hair colour (EYECLR, HAIRCLR); as well as number of solar keratoses (CLINSK) and skin cancers on all subjects. Any basal cell carcinoma or squamous cell carcinoma diagnosed clinically was biopsied, and confirmed by histology to be invasive skin cancer (HISTSCA).

Measurements were made of the reflectance of light of wavelength 650 nm from the skins of all subjects who attended during the first 2 days of the survey, a random sample of survey participants. An EEL Model 99 Reflectance Spectrophotometer (manufactured by Diffusion Systems Ltd, Hanwell, London) was used.[15] Reflectance at 650 nm is not affected by blood or carotene pigments in the skin and depends mainly on the amount of melanin pigment present, and to some extent on the thickness of the overlying skin.[7] The instrument was standardized initially and between subjects, so that reflectance values were relative to 100% reflectance from a standard white tile which itself had 85% reflectance of the absolute standard of a magnesium carbonate surface. Thus, high reflectance values indicate pale skin with little absorptive melanin pigment. Readings were made by one of two operators at six sites on each subject, namely the medial aspects of the right and left upper arms midway between axilla and elbow (UPPARMR, UPPARML); at the lateral aspects of both forearms midway between elbow and wrist (FORARMR, FORARML); and on the backs of both hands (HANDR, HANDL).

TABLE 1. Distribution of skin cancer and risk factors by sex in 346 males and 461 females in Nambour, Queensland, 1986

Occupational exposure	Outdoor	In/Out	Indoor			
Males (%)	41·0	35·5	23·5			
Females (%)	9·3	31·5	59·2			
Leisure exposure	Outdoor	In/Out	Indoor			
Males (%)	64·5	26·3	9·2			
Females (%)	38·8	37·7	23·5			
Sunburn	Never	Once	2–5 ×	> 5 ×		
Males (%)	12·1	12·4	43·4	32·1		
Females (%)	12·8	15·6	47·9	23·7		
Previous skin cancer	No	Yes				
Males (%)	79·9	20·1				
Females (%)	81·2	18·8				
Burn or Tan	Burn	Burn/Tan	Tan			
Males (%)	18·5	65·0	16·5			
Females (%)	29·1	56·6	14·3			
Skin colour (self)	Fair	Medium	Olive	Black		
Males (%)	60·1	31·5	8·1	0·3		
Females (%)	63·6	28·0	8·4			
Skin colour (doctor)	Fair	Medium	Olive	Black		
Males (%)	40·6	45·8	12·8	0·9		
Females (%)	47·0	42·0	10·7	0·3		
Eye colour (doctor)	Blue/ Grey	Light brown	Green hazel	Dark brown		
Males (%)	49·3	33·3	6·7	10·7		
Females (%)	41·4	38·3	7·0	13·3		
Hair colour, age 21 (doctor)	Blonde	Light brown	Ginger	Dark red	Dark brown	Black
Males (%)	8·4	35·1	3·2	1·7	42·6	9·0
Females (%)	8·0	39·6	5·0	4·3	37·6	5·4
Solar keratoses (doctor)	No	Yes				
Males (%)	49·7	50·3				
Females (%)	62·3	37·7				
Skin cancer (histology)	No	Yes				
Males (%)	96·8	3·2				
Females (%)	98·7	1·3				

All variables are coded in ascending order of categories as shown.

Analysis

Correlations between variables were investigated, as the primary concerns were to compare objective measurement of skin colour to subjective assessment and to evaluate the relation between objective measurement and standard outcomes and risk factors related to skin cancer. For ordinal variables, correlations were calculated assuming that there is a normal distribution of liability underlying the categories. PRELIS 1.8[16] was used to calculate separate correlation

matrices for males and females, with pairwise deletion of missing values. Between two continuous traits, Pearson correlations were calculated; between two ordinal variables polychoric correlations were used;[17] and a polyserial correlation was calculated between a continuous and an ordinal variable.[18]

RESULTS

Distribution of reflectance measurements

Reflectance measurements of skin colour were performed on 807 subjects, 346 males and 461 females (average age 44 years). Females showed higher mean reflectance than males at all sites. The difference between sexes was greatest for the lateral forearms and least for the medial surface of the upper arms, where the highest readings were obtained in both sexes (Table 2). The forearms had higher reflectance values than the hands in females, while the hands of males had the higher values. Laterality had little influence with the exception that the right forearm tended to be darker than the left in both sexes.

Inter-observer reliability of reflectance measurements

Two observers made all the reflectance measurements. Inter-observer reliabilities were calculated as Pearson correlations between independent reflectance measurements taken by both observers in 43 subjects at all six sites (Table 2). All were highly significant and large, though the magnitude of reliability at a given site was directly proportional to the variance of

TABLE 2. Distribution and inter-observer reliability of skin reflectance measurements and age in 346 males and 461 females in Nambour, Queensland, 1986

		Mean	SD	Skewness	Range	Reliability*
Age	Male	44·3	14·2	0·069	20–69	
	Female	44·4	13·1	0·059	20–69	
Upper arm						
Left	Male	74·4	4·6	−0·982	48–86	0·79
	Female	77·2	3·6	−0·510	60–85	
Right	Male	74·1	4·5	−0·903	49–85	0·79
	Female	76·8	3·6	−0·800	55–86	
Forearm						
Left	Male	50·4	7·8	−0·168	28–69	0·96
	Female	65·9	5·1	−0·605	43–81	
Right	Male	47·3	8·2	0·196	23–73	0·95
	Female	63·7	5·5	−0·899	35–76	
Hand						
Left	Male	55·7	6·7	−0·506	30–75	0·92
	Female	61·7	6·3	−0·193	40–80	
Right	Male	55·1	6·5	−0·229	34–72	0·89
	Female	62·0	6·2	−0·459	31–80	

* Pearson correlation of measurements by two observers of 43 subjects.

reflectance measurements at that site. Thus, reliability of measurement was greatest for the forearm (0·95) and least for upper arm (0·79), where variance in skin colour was only about 30% of that on the forearm (Table 2). Measurement error therefore formed a greater proportion of the total variance of reflectance on the upper arm.

Prevalence of risk factors and outcomes

Conventional sun-related risk factors for skin cancer were predominant in males (Table 1), and these results have been discussed in detail elsewhere.[14] Dermatologists evaluating skin colour rated the majority (46%) of men as having medium complexions and the majority (47%) of women as having fair skin. By contrast, 60% of men and 64% of women considered themselves to have fair skin. Half of all the males examined had solar keratoses, and 3% had skin cancer. Fewer females were affected and 38% had keratoses and 1% skin cancer (Table 1).

Correlation between skin colour and outcomes

Despite the small number of skin cancers diagnosed during the survey, there were significant correlations ($P < 0{\cdot}001$) with several reflectance measurements in both males and females, though actual patterns of association were variable (Table 3). The presence of skin cancer diagnosed in 11 males was correlated with high reflectance values (pale skin) on the medial aspect of the upper arms, but was not related to measured pigment of forearms or backs of hands. Skin cancer diagnosed in five females was correlated with low reflectance values on the medial upper arms and on the forearms, with no association with colour of backs of hands. Solar keratoses showed quite different associations (Table 3). Among males (174 of whom were affected), keratoses were correlated with high reflectance values of the medial upper arm, and with low values on the lateral forearms and hands. Keratoses in females (174 affected) were associated ($P < 0{\cdot}001$) only with low reflectance (dark pigmentation) on the backs of the hands.

Prevalence of skin cancer and self-graded fair skin colour in males were highly correlated—greater than skin colour as assessed by the dermatologist or objective measurement of pigmentation. Correlations between prevalence of solar keratoses among males and both self-reported fair skin colour and measured pale pigmentation on medial upper arms were similar, and the highest correlations were with darkly pigmented forearms and backs of hands. There were moderate negative correlations between high reflectance from the upper arms (pale skin) and prevalence of skin cancer and of solar keratoses in females, but the reverse with skin colour as perceived by dermatologists and self.

Correlations of skin colour with other risk factors

High reflectance of the upper arms was associated with increasing age in males but not in females. Low reflectance from forearms and hands (dark pigmentation) was associated with increasing age in both sexes ($P < 0{\cdot}001$) (Table 3). Other risk factors for skin cancer which were significantly correlated with low reflectance values on forearms and hands among males and females (though site-specific values varied) were outdoor occupations and leisure activities. High reflectance values on upper arms were associated with number of episodes of severe sunburn, and in males, previous skin cancer; propensity to burn rather than tan; and hair colour. Eye colour was associated with reflectance values in males, but showed no association in females (Table 3).

Correlations between subjective and objective measurements of skin colour

Significant correlations were observed between subjective rating (by dermatologists and self) of

TABLE 3. Correlations (× 100) of skin reflectance measurements with outcome variables and other risk factors in the Nambour Skin Cancer Survey, 1986

	Males (n = 345–346)																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 AGE	100	−08	−27	−21	45	−10	−08	−03	02	−19	73	49	20	26	−31	−32	−43	−35
2 OCCEXP	−17	100	20	15	−14	−11	−20	11	03	05	−19	−07	13	07	23	22	28	26
3 LESEXP	−07	14	100	03	−25	−02	−11	13	07	03	−30	−08	−02	−01	24	23	27	16
4 SUNBURN	−34	03	−03	100	02	−20	−18	−10	01	−09	−03	03	05	05	13	05	18	16
5 PREVSKCA	35	−07	−09	−02	100	−20	−10	−13	−16	−26	54	51	25	24	−12	−17	−16	−04
6 SKCLSELF	03	02	−09	−15	−18	100	53	43	36	65	−26	−91	−24	−26	−21	−21	−13	−23
7 BURNTAN	10	−19	−16	−32	−07	55	100	11	14	33	−25	−13	−22	−20	−05	−10	−14	−20
8 EYECLR	−12	01	−02	−12	−16	31	08	100	42	52	−10	−08	−23	−20	−26	−27	−08	−16
9 HAIRCLR	01	−09	−06	−16	−01	27	17	34	100	55	−02	−21	−23	−16	−30	−35	−14	−23
10 SKCLDERM	−04	−09	−12	−22	−20	66	48	39	45	100	−48	−60	−30	−35	−21	−20	−12	−19
11 CLINSK	53	−15	−04	−10	37	−30	−07	−17	−15	−39	100	93	20	26	−32	−28	−30	−18
12 HISTSCA	10	−32	−10	−04	−01	−25	11	15	14	−11	28	100	33	30	04	02	02	06
13 UPPARML	−04	−01	03	03	−03	−29	−21	−05	−07	−20	−07	−20	100	71	25	26	18	22
14 UPPARMR	01	06	10	04	03	−37	−31	−09	−11	−28	13	−18	74	100	18	16	14	18
15 FORARML	−17	18	19	10	−11	−42	−43	−10	−20	−38	01	−21	39	45	100	85	52	59
16 FORARMR	−18	14	25	11	−01	−42	−44	−09	−23	−34	02	−19	36	40	79	100	49	58
17 HANDL	−50	14	09	28	−17	−35	−31	00	−02	−22	−16	07	28	31	60	52	100	80
18 HANDR	−49	15	14	28	−18	−31	−29	01	−06	−22	−17	−06	33	32	59	58	83	100

Females (n = 457–461)

For males (above diagonal), $P < 0{\cdot}05$ for $|r| > 0{\cdot}11$, $P < 0{\cdot}001$ for $|r| > 0{\cdot}17$. Corresponding values for females (below diagonal) are 0·09 and 0·15. Intercorrelations of continuous variables (1, 13–18) are Pearson, of ordinal variables (2–12) are polychoric, and between continuous and ordinal variables are polyserial.

fair skin and objective measurement of high reflectance at all sites, and correlations were highest for the upper arms in males, and the forearms in females (Table 3). Compared to dermatologists' assessments, self-reporting of skin colour by females was more highly correlated with the reflectance values, whereas that by males was less or similarly correlated.

There are 306 correlations listed in Table 3 so some of them will be significant by chance. Nevertheless, the 95% confidence intervals are around $\pm 0{\cdot}10$ so the point estimates give a fair idea of the importance of relationships between variables. In many cases, confidence in a correlation is enhanced if it is replicated in both sexes, although there may be a genuine sex difference.

DISCUSSION

These quantitative measurements of skin colour in an unselected population confirm that exposed skin surfaces are considerably darker in males than females, while the colour of skin not exposed to the sun is slightly darker in males (Table 2). Sexual dimorphism in inherent skin colour has long been observed,[19] and may be related to differential levels of melanocyte stimulating hormones.[20] That men in general spend much more time outdoors than women (Table 1) suggests that tanning (facultative pigmentation), and perhaps skin thickening in response to sun exposure, are responsible for the sex variation in colour of exposed skin. Another factor contributed to the lower reflectance values in males, namely dark hair which occurs more commonly on the arms. For this reason the forearms, which are less sun-exposed than the backs of the hands overall (evidenced by lighter colour of forearms than backs of hands in females), showed deeper pigmentation than the hands in males. The darker colour of the right forearm compared to the left in both sexes is presumably due to sun exposure while driving.

Light innate skin colour was significantly associated with skin cancer in both males and females. In the females the pale forearms were also associated with skin cancer. Keratoses occurred in both males and females with a naturally light skin, but whose hands tended to be darkly tanned. Inconsistencies in patterns of association between skin cancers and keratoses may have been partly due to the small number of subjects with prevalent skin cancer, or they could signify different aetiologies of basal cell carcinoma (the predominant type of skin cancer) and solar keratoses.

These findings agree with the finding that actinic lesions are most frequently seen in fair skinned people who are repeatedly outdoors. On this basis, the level of correlation between cancers and keratoses on the skin and objective skin colour measurements, compared to qualitative skin colour (graded by an expert or self), were lower than expected. The low correlations with reflectance measures may indicate that it is not skin colour *per se*, but some combination of factors that determines the development of skin tumours. Many of these factors relate to sun-sensitivity of the skin, e.g. propensity to sunburn, and are thus significantly correlated with skin colour (Table 3), and with the ability to tan.

Neither the examining dermatologists nor the subjects themselves accurately graded skin colour (Table 3). As subjects and dermatologists were asked to rate untanned skin colour, the correlations of interest are between upper arm measurements and ratings, the highest of which ($r = -0{\cdot}37$) was between self-rating and right upper arm reflectance in females. By this criterion, female subjects rated their own skin colour slightly more accurately than did dermatologists, whereas in males the reverse was true. However, somewhat higher correlations between tanned skin measurements on forearms and both self and doctor ratings were seen in females, suggesting that their perception of skin colour was more influenced by tanned than

untanned skin colour, in spite of contrary instructions (this effect was not seen in males). Variability of pigmentation between males and females with advancing age as shown here, has also been observed in Indian women by Banerjee.[20] The reason for the lack of correlation between skin reflectance and eye colour among females in our study is unknown.

In conclusion, our study confirms the importance of skin colour of unexposed and sun-exposed sites, in relation to skin cancer. While the human eye is unable to estimate pigmentation precisely, it would seem that 'skin colour' ratings by dermatologists, and as perceived by self, are useful composite indicators of skin cancer susceptibility.

ACKNOWLEDGMENTS

This study was funded by the Queensland Cancer Fund and the Australian Cancer Society. Dr Green was supported by a Neil Hamilton Fairley Fellowship of the National Health and Medical Research Council of Australia. We thank Lea Mangahas and Adam Bain for taking the reflectance measurements.

REFERENCES

1 Beral V, Evans S, Shaw H, Milton G. Cutaneous factors related to the risk of malignant melanoma. *Br J Dermatol* 1983; 109: 165–72.
2 Sorahan T, Grimley RP. The aetiological significance of sunlight and fluorescent lighting in malignant melanoma. *Br J Cancer* 1985; 52: 765–9.
3 Green A, Bain C, Maclennan R *et al.* In: *Recent Results in Cancer Research: Epidemiology of Malignant Melanoma* (Gallagher RP, ed), Berlin: Springer–Verlag, 1986; 76–97.
4 Elwood JM, Williamson C, Stapleton PJ. Malignant melanoma in relation to moles, pigmentation, and exposure to fluorescent and other lighting sources. *Br J Cancer* 1986; 53: 65–74.
5 English JSC, Swerdlow AJ, MacKie RM *et al.* Relation between phenotype and banal melanocytic naevi. *Br Med J* 1987; 294: 152–4.
6 Edwards EA, Duntley SQ. Pigments and colour of living human skin. *Amer J Anat* 1939; 65: 1–33.
7 Walsh RJ. Variation in the melanin content of the skin of New Guinea natives at different ages. *J Invest Dermatol* 1964; 42: 261–5.
8 Rigters-Aris CAE. Relationships between skin reflectances at several wavelengths in inter and intrapopulation comparisons. *Human Biology* 1973; 45: 613–26.
9 Clark P, Stark AE, Walsh RJ *et al.* A twin study of skin reflectance. *Ann Human Biol* 1981; 6: 529–41.
10 Little MA, Woolf ME. Skin and hair reflectance in women with red hair. *Ann Hum Biol* 1981; 8: 231–41.
11 Spurgeon JH, Meredith HV, Onuoha GBI. Skin colour comparisons among ethnic groups of college men. *Am J Phys Anthrop* 1984; 64: 413–8.
12 Holman CDJ, Armstrong BK. Pigmentary traits, ethnic origin, benign naevi, and family history as risk factors for cutaneous malignant melanoma. *JNCI* 1984; 72: 257–66.
13 Hertzman C, Walter D, From L *et al.* Observer perception of skin colour in a study of malignant melanoma. *Am J Epidemiol* 1987; 126: 901–11.
14 Green A, Beardmore G, Hart V *et al.* Skin cancer in a Queensland population. *J Am Acad Dermatol* 1988; 19: 1045–52.
15 Weiner JS, Lourie JA. Human biology. *A Guide to Field Methods*. Oxford: Blackwell Scientific Publications, 1969; 157–61.
16 Joreskog KG, Sorbom D. PRELIS. A program for multivariate data screening and data summarisation. A preprocessor for LISREL. Scientific Software Inc., Mooresville, Ind. 1986.
17 Olsson U. Maximum-likelihood estimation of the polychoric correlation coefficient. *Psychometrika* 1979; 44: 443–60.
18 Olsson U, Drasgow F, Dorans NJ. The polyserial correlation coefficient. *Psychometrika* 1982; 47: 337–47.
19 Frost P. Human skin colour: A possible relationship between its sexual dimorphism and its social perception. *Perspectives Biol and Med* 1988; 32: 38–58.
20 Banerjee S. Pigmentary fluctuation and hormonal changes. *J Genet Hum* 1984; 32: 345–9.