Comparison of Munsell® color chart assessments with primary schoolchildren's self-reported skin color

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Abstract

Background: Skin color is related to human health outcomes, including the risks of skin cancer and vitamin D insufficiency. Self-perceptions of skin color may influence health behaviours, including the adoption of practices protective against harmful solar ultraviolet radiation levels. Misperception of personal risk may have negative health implications. The aim of this study is to determine whether Munsell® color chart assessments align with child self-reported skin color.

Methods: Two-trained investigators, with assessed color acuity, visually classified student inner upper arm constitutive skin color. The Munsell® classifications obtained were converted to Individual Typology Angle (ITA) values and respective Del Bino skin color categories after spectrocolorimeter measurements based on published values/data. As part of a written questionnaire on sun protection knowledge, attitudes, and behaviours, self-completed in class time, students classified their end of winter skin color. Student self-reports were compared with the ITA-based Del Bino classifications. A total of 477 New Zealand primary students attending 27 randomly selected schools from five geographic regions. The main measures were self-reported skin color and visually observed skin color.

Results: A monotonic association was observed between the distribution of spectrophotometer ITA scores obtained for Munsell® tiles and child self-reports of skin color, providing some evidence for the validity of self-report among New Zealand primary school children, although the lighter colored ITA defined groups were most numerous in this study sample. Statistically significant differences in ITA scores were found by ethnicity, self-reported skin color, and geographic residence ($P < 0.001$). Certain Munsell® color tiles were frequently selected as providing a best match to skin color.

Conclusion: Assessment using Munsell® color charts was simple, inexpensive, and practical for field use and acceptable to children. The results suggest that this method may prove useful for making comparisons with other studies using visual tools to assess skin color. Alignment between the ITA distribution derived from the Munsell® assessment and child skin color self-reports could probably be improved, particularly with the addition of another 'light'/'white' color category in the self-report instrument.

Key words: Munsell®color charts – skin color – primary schoolchildren

Skin color is related to several health outcomes, including the risks of skin cancer and vitamin D insufficiency [1]. Self-perceptions of skin color may influence health behaviour, such as the adoption of practices that protect against the risk of exposure to either excessive or insufficient ultraviolet radiation (UVR). Any misperception of such personal risks may influence behaviour and have potentially serious negative health consequences. For example, a tendency for those with fair skin to self-classify into a darker skin color category, known as 'the Dark Shift' [2], has been reported and has the potential to lead to an underestimation of personal skin cancer risk and a misinterpretation of some public health messages. While we acknowledge that the Fitzpatrick Skin Phototype (FSPT) [3] shows the best correlation with medically important health outcomes [4] and that skin color does not correlate well with FSPT [5, 6], in general, people know their perceived skin color and not their FSPT, hence, behavioural messages are directed to individuals using descriptors such as 'people with fair skin or white skin' or 'people with dark skin'. Therefore, understanding the relationship between perceived skin color and measured skin color is of utmost importance to public health practitioners and researchers for the crafting of sun awareness messages and advice, and toward the prevention of adverse health effects, especially skin cancer.

Skin color is determined by the surface layers of the epidermis, pigmentation and the filling/emptying of cutaneous and subcutaneous capillary vessels [7]. Skin color can be measured by either *reflectometry*, for example, using a hand-held narrowband reflectance spectrometer; *colorimetry*, for example, with a tristimulus colorimeter; or by *visual standards* which entail the use of color atlases [7, 8]. The Munsell® system is based on a color atlas in which colors are represented in a three dimensional solid and the Munsell Soil Color Charts Year 2000 Revised Washable Edition (hereafter, referred to as the Munsell®) contains a range of color tiles in a loose-leaf binder with perforated cards to facilitate contiguous matching. In addition to its use in geology and other areas, it is also recommended for assessing human skin color [9].

The Munsell® color tiles are arranged in a three dimensional expression by hue, value, and chroma. Hue describes the color's relation to red, yellow, green, blue, and purple (sheet descriptor), value indicates lightness (sheet line number) and chroma indicates strength (sheet column number). Color may be described either by using the Munsell® color notation, for example, 5YR (sheet) 6/3 (line/column number), or by name, for example, 'light reddish brown'.

The Munsell® charts were used to assess the constitutive skin color of a sizeable sample of New Zealand primary school students as part of a broader skin cancer primary prevention research project which studied personal solar UVR exposure [10]. It was the preferred method for that project because no physical pressure is needed when holding the chart against the skin (making it non-invasive, safe, and non-threatening); it requires no data processing software; it is relatively inexpensive when compared with the use of other instruments; it provides an international standard of color; it is readily portable, quick and easy to use; and it was thought likely to be acceptable to children [11]. At that time, three published studies were identified which reported using the Munsell® system for classifying skin color: one assessed a nipple-areola [12], and one the skin overlaying a vein [13], whereas another involved the use of goggles fitted with monochromatic filters and a 32-step Munsell® neutral value scale to visually grade skin color [14]. These studies suggested that inter-observer variation and observer-error could potentially be reduced for experienced and trained observers. Subsequently, in 2013 and 2014, the use of Munsell® charts for skin color assessment was validated against spectrophotometer readings, and acceptable validity and inter- and intra-rater reliability were found when assessing a sample of 280 New Zealand tertiary students [11].

In the light of this recently published evidence, we report our findings regarding the Munsell®-derived Individual Typology Angle (ITA) [15-17] values for the constitutive skin color of a sample of New Zealand primary school students. Despite these data having been collected in 2004–2005, they have never before been published because additional research was required to validate the use of the Munsell® color charts for skin color assessments (now completed) [11], and here we suggest that the Munsell® color charts may be used among children in addition to adults. Furthermore, we report our investigation of the associations of these ITA values and the Del Bino skin color categories with student self-reports of skin color. Finally, we consider both the potential usefulness and limitations of the Munsell® visual skin color assessment method, when public health practioners and researchers are working within a limited budget among a sizable population of primary school students in the field.

Methods

The study is described elsewhere [10] and the following is a brief overview along with more detailed information about the specific measures of interest used here. Over a 6-month period, 22 October to 9 December 2004 and 1 February to 13 April 2005, 477 primary students (71.4% participation rate, 477/668) in school Levels 4 and 6 (national modal ages of 8 and 12 years, respectively) from a randomly selected sample of 27 schools (27 of 30 schools invited representing a 90% participation rate) in five geographic regions throughout New Zealand were assessed by visual inspection for their constitutive skin color.

The two investigators (CYW and VAH) who administered the Munsell® classification subsequently undertook the Online Color Challenge based on the official FM100 Hue Test by X-Rite (FM 100 Hue Test) (http://www.xrite.com/online-color-test-challenge) to assess their color acuity [18]. The error scores obtained (11 and 24, respectively) were considered favorable when compared to others of their age group (30–39 years), for whom the documented mean total error score is 50, where 0 is defined as 'perfect' and 99 as 'low' color acuity. The Munsell® charts used in this study were purchased purposefully for the fieldwork and the color tiles were free from damage and discoloration.

The two investigators were trained to conduct the visual assessments using a standard protocol to minimize intra- and inter-researcher variation. Working from the four yellow-red Munsell® charts which cover the skin color range, and following the sequence 2.5YR, 5YR, 7.5YR, and 10YR, each chart was held up against the upper inner arm of each student. The chart most closely related to overall skin tone was selected and then placed against the skin, again, to select the color tile that best matched student skin color. The assessments were carried out in daylight conditions indoors during school hours, using the gray mask for light samples. The anatomic site chosen was selected, because it is not usually exposed to sunlight and has been used in other studies [19, 20]. None of the students had any obvious skin blemishes on the area assessed. The assessment was only done when the student had been observed in a resting state for at least 30 min following physical exercise to allow time for the skin to return to its normal color.

In addition, as part of a comprehensive, self-completed questionnaire to assess sun exposure and protection knowledge, attitudes and behaviours, students were asked: 'How would you describe your natural, untanned skin color, for example, under your upper arm, at the end of winter?' The response options provided were: 'white', 'light brown', 'brown', 'dark brown', and 'black'. The questionnaire was completed during class time.

The Munsell® classifications obtained were recorded and converted to ITA values and the respective Del Bino skin color categories [15-17]. This was done by using the ITA values for Munsell® tiles reported and described in detail in supplementary files by Reeder et al. [11]. Briefly, a Konica Minolta M-600d spectrophotometer was used to obtain readings of each of the Munsell® color tiles. The CIE L^*, a^* and b^* parameters on each of the Munsell color tiles was measured with a spectrophotometer in standard conditions (i.e. D65 lighting, 10° observer). These L^*, a^* and b^* values for each color tile were entered into a Microsoft Excel spreadsheet and were used to calculate color tile ITA values according to the following equation [15]:

$$\text{ITA} = \tan^{-1}\left(\frac{L^* - 50}{b^*}\right) \times \frac{180}{\pi}$$

where L^* is the difference along the lightness–darkness axis and b^* is the difference along the yellow–blue axis. Six skin classifications are defined using ITA values, namely, Very light: ≥55°; Light: ≥41° to <55°; Intermediate: ≥28° to <41°, Tanned: ≥10° to <28°; Brown: ≥−30° to <10°; and Dark: ≤−30°.

Student self-reports were compared with the Del Bino ITA distribution and the association between the measures was investigated (Fig. 1). Box and whisker plots are used to visually summarize the association between ITA value and self-reported skin color while also showing the bands of ITA values associated with each Del Bino skin color category.

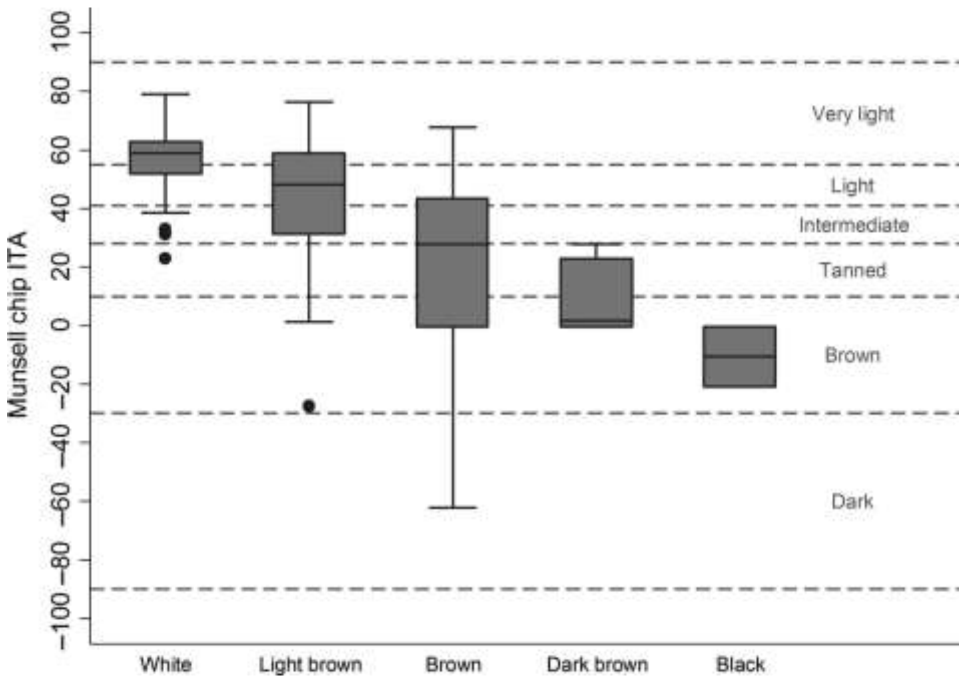

Figure 1. Medians and interquartile ranges for spectrophotometer readings of Munsell color tile ITA scores with Del Bino skin color categories (gray labels) against self-reported survey skin color (*x*-axis). This figure shows the observed monotonic distribution of self-reported skin color across ITA values objectively measured by spectrophotometer from Munsell color tiles and provides evidence of the validity of self-reported skin color for primary school age boys and girls in New Zealand.

Table 1. Participant characteristics and associated median, 25th and 75th percentile ITA scores

Response item	**Frequency (*n*, %)**	**Median ITA**	**ITA percentiles**		***P*-value[a]**
			25th	**75th**	
Sex					
Female	243 (52.0)	51.6	31.3	62.6	0.058
Male	224 (48.0)	51.6	33.0	62.8	
Missing	10				
Self-reported ethnicity (prioritizsed)					<0.001
European	273 (58.3)	59.0	48.2	62.8	ad
Māori	93 (19.9)	48.2	27.8	59.0	be
Pacific	43 (9.2)	31.3	6.1	39.5	c
Asian	27 (5.8)	22.9	1.7	33.0	c
All other	11 (2.4)	51.6	48.2	59.0	de
Don't know	21 (4.5)	51.6	31.3	62.8	de
Missing	9				
Self-reported skin color					<0.001
White	178 (38.2)	59.0	51.6	62.8	a
Light brown	234 (50.2)	48.2	31.3	59.0	b
Brown	47 (10.1)	27.8	-0.3	43.4	c
Dark brown (*n* = 5)/Black (*n* = 2)	7 (1.5)	-0.3	-0.3	22.9	c
Missing	11				
School year					
Level 4	209 (43.8)	51.6	33.0	62.8	0.544
Level 8	268 (56.2)	51.6	31.3	62.6	
Geographic center (N to S)					<0.001
Auckland	122 (25.6)	33.0	22.9	51.6	a
Hamilton	92 (19.3)	39.5	27.8	51.6	a
Wellington	105 (22.0)	51.6	33.0	59.0	b
Canterbury	54 (11.3)	61.0	54.9	65.3	c
Otago/Southland	104 (21.8)	62.7	54.9	67.7	c

[a] Mann–Whitney–Wilcoxon (for sex and year) or Kruskall–Wallis (for all others). Where the overall effect is statistically significant, different letters indicate statistically significant differences between pairs of groups using *posthoc* Mann–Whitney–Wilcoxon tests.

Frequencies are presented for all categorical variables of interest [sex, prioritized self-reported ethnicity (from highest to lowest priority: Māori, Pacific, Asian, Other, and European), self-reported skin color (with collapsing where appropriate due to small counts), school year, and area where the school is located] (Table 1). Median Munsell color tile ITAs (i.e. the median of three readings of ITA on one Munsell color tile) are shown for each level of each variable, alongside 25th and 75th percentiles. For variables with more than two levels, Kruskal–Wallis tests were used to identify overall differences in location, with Wilcoxon–Mann–Whitney tests used to identify statistically significant pairwise differences where the overall test was statistically significant. For variables with two levels (sex and school year), Wilcoxon–Mann–Whitney tests were performed in the first instance. When results are presented, where there is a lack of evidence for a difference between two levels of a variable, these two levels are shown with a shared letter. Similarly, where there is evidence of a difference between two levels of a variable, no shared letter is shown. Stata 13.1 (Statacorp, 2013, Stata Statistical Software: Release 13; StataCorp LP, College Station, TX, USA) was used for all analyses and all statistical tests were performed at the two-sided 0.05 level.

Ethical approval for the study was obtained through the University of Otago Human Ethics Committee (certificate number 04/028).

Results

Median ITA scores by sample demographic and self-reported skin characteristics are presented in Table 1. No statistically significant differences were found in ITA scores by sex or school year. In the case of skin color, there is evidence of significant difference between all combinations of the four self-reported categories aside from between 'Brown' and 'Dark brown/black'. The observed geographical differences in ITA followed a plausible latitudinal pattern from the lowest positive median value (i.e. darker) in the northern Auckland and Hamilton, where greater proportions of the resident population are of Pacific, Māori, or Asian ethnicity (and UVI levels tend to reach higher mean summer levels), to the highest value (i.e. lighter) in the southern Otago and Southland. The ethnicity effect is similarly plausible in terms of statistically significantly increasing darkness going from European to Māori to Pacific and Asian.

Only 40 of the possible 141 color tiles on the four charts used (or the possible 322 color tiles on the nine possible charts were used in this study), reflecting 28% (or 12% use) (Table 2).

Table 2. Munsell color tiles: selection frequency and Del Bino category ranked by ITA values

Card	Hue	Value	Chroma	*n*	Del Bino category	ITA
3	7.5YR	3	2	2	Dark	−62.20
3	7.5YR	4	3	2	Dark	−29.73
4	10YR	4	3	3	Brown	−27.41
3	7.5YR	4	4	1	Brown	−24.22
4	10YR	4	4	2	Brown	−21.14
3	7.5YR	5	4	10	Brown	−0.26
4	10YR	5	3	7	Brown	1.37
4	10YR	5	4	11	Brown	1.71
2	5YR	5	4	1	Brown	1.97
3	7.5YR	5	3	1	Brown	6.10
3	10YR	6	4	31	Tanned	22.89
3	7.5YR	6	4	19	Intermediate	27.82
1	2.5YR	6	3	1	Intermediate	29.96
4	10YR	6	3	26	Intermediate	31.34
3	7.5YR	6	3	19	Intermediate	33.04
2	5YR	6	3	1	Intermediate	38.57
4	10YR	7	4	16	Intermediate	39.51
3	7.5YR	7	4	1	Light	43.33
4	10YR	6	2	2	Light	43.36

Card	Hue	Value	Chroma	*n*	Del Bino category	ITA
3	7.5YR	6	2	3	Light	43.70
1	2.5YR	7	3	4	Light	45.63
4	10YR	7	3	53	Light	48.19
2	5YR	7	4	1	Light	48.42
3	7.5YR	7	3	47	Light	51.61
2	5YR	7	3	9	Light	53.50
1	2.5YR	7	2	13	Light	54.92
4	10YR	8	3	1	Very light	57.40
4	10YR	7	2	44	Very light	58.95
3	7.5YR	8	3	4	Very light	59.32
2	5YR	7	2	25	Very light	62.64
3	7.5YR	7	2	58	Very light	62.79
1	2.5YR	8	2	2	Very light	63.98
4	10YR	8	2	9	Very light	65.25
3	7.5YR	8	2	16	Very light	67.69
4	10YR	7	1	1	Very light	69.69
3	7.5YR	7	1	9	Very light	72.25
2	5YR	8	2	9	Very light	73.62
2	5YR	7	1	3	Very light	74.59
3	7.5YR	8	1	7	Very light	76.38
2	5YR	8	1	3	Very light	78.97

The relation between the self-reported skin color categories and the spectrophotometer ITA readings of the Munsell color tiles selected by the assessors (also showing the Del Bino skin color categories) are presented in Fig. 1. Despite overlapping ranges, the observed monotonic distribution of self-reported skin color across ITA values objectively measured by spectrophotometer from Munsell color tiles provides evidence of the validity of self-reported skin color for primary school age boys and girls in New Zealand.

Discussion

Although other technical instruments may be more precise, recent research demonstrates that the Munsell® color tiles, as used by the assessors in this study, can be a valid and reliable measure of skin color for classification into suitable risk groups for targeting public health interventions [11]. This study extends those findings by providing some evidence to support the validity of child self-reported skin color against spectrophotometer measures of Munsell tile ITA values. The intention of the study was not to compare the ITA values measured on the Munsell color tiles with ITA values measured directly on the children's inner arm; however, this could be done in future studies. Nevertheless, our findings suggest opportunities for categorization of skin color to be improved. In our effort to facilitate child self-reports, we may have reduced the available response categories to too few. We offered a choice of three categories of ‘brown’, but provided only a single ‘white’ category (to balance the single ‘black’ category). We now consider it likely that, had we offered a second category at the lighter end of the spectrum, similar to the ‘light’ Del Bino category, fewer children would have been likely to select the most commonly reported ‘light brown’ category, resulting in better color discrimination, overall.

One of the challenges and potential biases associated with using the Munsell® charts was the need to find good, usual indoor lighting when making assessments in the field. While such observations were made in non-standardized conditions, the aim was to test the Munsell® color charts in real world fieldwork conditions and not controlled laboratory settings. Also, improved accuracy of assessment may be possible if the Munsell tiles were mounted on transparent plastic sheets, thereby providing a larger visible surface area to help overcome difficulties such the texture differences between the color tiles and the irregular skin surface, geometry, and shape with which they are being matched. The color tiles could, perhaps, also be presented closer together to facilitate matching the relatively small variations in skin color that commonly occur among the predominantly Caucasian population found in New Zealand. Some of the ITA values directly measured on the Munsell color tiles are very similar and further rationalization might have been possible. There was evidence that the two assessors frequently selected certain Munsell color tiles (Table 2), suggesting a potential for simplification by means of a rationalization and reduction in the available options within each Del Bino skin color category except ‘tanned’. The use of a color ‘wheel’ could possibly facilitate this, while still permitting a wide choice.

Conclusion

We found that assessment using Munsell® color charts was simple, inexpensive, and practical for field use as well as acceptable to children. The results suggest that this method may prove useful for making comparisons with other studies using visual tools to assess skin color. Alignment between the ITA distribution derived from the Munsell® assessment and child skin color self-reports could probably be improved, particularly with the addition of another ‘light’/’white’ color category in the self-report instrument. Use of the Munsell® color charts among populations containing a higher proportion of darker skin colors than in the study reported here would help clarify its applicability to these groups.

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Disclosure

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University of Otago and is presently employed by the Council for Scientific and Industrial Research in South Africa.

Author Contribution

Dr Wright and Mr Gray had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design*: Drs Wright and Reeder. *Acquisition, analysis, and interpretation of data*: Dr(s) Wright, Hammond, Reeder and Mr Gray. *Drafting of the manuscript*: Dr(s) Wright, Reeder, and Mr Gray. *Critical revision of the manuscript for important intellectual content*: Dr(s) Wright, Reeder. *Statistical analysis*: Mr Gray. *Obtained funding*: Dr(s) Wright, Reeder. *Administrative, technical, or material support*: Ms Jopson, Ms Huston, Mr Wilkes. *Study supervision*: Dr Reeder.

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