In multiple situational light settings, visual observation for skin colour assessment is comparable with colorimeter measurement

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Abstract

Background: Finding inexpensive and reliable techniques for assessing skin colour is important, given that it is related to several adverse human health outcomes. Visual observation is considered a subjective approach assessment and, even when made by trained assessor, concern has been raised about the need for controlled lighting in the study venue. The aim of this study is to determine whether visual skin colour assessments correlate with objective skin colour measurements in study venues with different lighting types and configurations.

Methods: Two trained investigators, with confirmed visual acuity, visually classified the inner, upper arm skin colour of 556 adults using Munsell® colour classifications converted to Individual Typology Angle (°ITA) values based on published data. Skin colour at the same anatomic site was also measured using a colorimeter. Each participant was assessed in one of 10 different buildings, each with a different study day. Munsell®-derived °ITA values were compared to colorimeter °ITA values for the full sample and by building/day.

Results: We found a strong positive, monotonic correlation between Munsell® derived °ITA values and colorimeter °ITA values for all participants (Spearman $\rho = 0.8585$, $p<0.001$). Similar relationships were found when Munsell® and colorimeter °ITA values were compared for participants

assessed in the same building for all ten buildings (Spearman ρ values ranged from 0.797 to 0.934, all correlations were statistically significant at $p<0.001$).
Conclusion: It is possible to visually assess individual skin colour in multiple situational lighting settings and retrieve results that are comparable with objective measurements of skin colour. This was true for individuals of varying population groups and skin pigmentation.

Keywords: Munsell® color charts, skin colour, lighting, colorimeter, Individual Typology Angle (ITA).

Introduction

Accurate identification of skin colour is important since skin colour influences disease risk factors, such as for skin cancer (1) and vitamin D deficiency (2), and affects sun protection choices for disease prevention (3). Beside self-report, techniques used to identify skin colour may be objective, such as spectrophotometry, or subjective, for example, visual observation by a trained professional. The latter is considered a reasonably reliable, less invasive and inexpensive approach to skin colour observation when precise skin colour measures are not required (4). This is particularly useful in epidemiology studies and health-based interventions for the targeting of appropriate health messages focussed on skin cancer prevention and other health risks. However, the visual observation technique for skin colour identification has been criticised when used in the field in multiple, situational light settings. Light, among other factors, can influence how colour is seen (5). However, field observations of skin colour, using colour atlases such as the Munsell® colour system or a custom-made study-specific skin colour chart (6), are unlikely to take place in a controlled light environment.

A study among university students confirmed the usefulness of Munsell® colour charts for skin colour assessment in fieldwork contexts (4). Measurements were made during the evening in rooms with standard Philips 840 fluorescent strip lamps. In another publication, we reported how child self-reported skin colour compared well with Munsell® colour chart tiles selected by trained researchers (7). Our readings were performed in daylight conditions inside the classroom, but no lighting measures were recorded. Although both of these studies reported the lighting environments within which skin colour observations were made, in neither case was it possible to analyse the results in relation to lighting differences.

An opportunity was identified to explore the influence of lighting differences on skin colour with data collected using both spectrophotometry and the Munsell® colour charts in a recent study carried out

among South Africans (8). This study took place in 10 different buildings with various light settings, on 10 different days. The present article was designed to answer one specific question, namely, whether Munsell® skin colour measurements correlate with objective skin colour measurements in study venues with different lighting types and configurations.

Materials and methods

Sample selection. A convenience sample was drawn from participants of a wellness screening programme offered to employees of the Council for Scientific and Industrial Research (CSIR) in Pretoria (25° 45.317' S; 28° 16.606' E). Sample size calculations (in accordance with the needs of the larger study) were based on the following equation:

$$= \frac{\left((z)^2 \times p(1-p)\right)}{(me)^2}$$

Where *n* is the required sample size, *z* is a confidence level at 95% (standard value of 1.96), *p* is the proportion of interest in our study area (unknown for this study, so set to 0.5) and a margin of error of $\pm$5%, so a value of 0.05 was used. Under these conditions, a sample size of 385 participants was needed, assuming any cluster effects to be negligible.

Procedures. All participants were treated by following a standard protocol, and procedures were pre-tested and piloted. Sampling took place on the 6-10, 14-16 and 21-22 October 2014 in a different building venue each day. The lighting type and configuration in each building was recorded (Table 1). Participants attended the wellness screening first and were then recruited to participate in the study. Information in a follow-up email about a participant's skin phototype was offered as an incentive. Participants were provided with an information sheet and consent form, and the study purpose and procedures were explained verbally. Consenting participants were assigned a unique identifier code. Participants were asked to wipe the inner side of their non-dominant arm with a wet wipe to remove any residual skin products. The inner upper arm is the anatomic site recommended for assessing natural, untanned skin colour in a minimally invasive way (9,10). Participants also answered a short questionnaire to assess phenotypic characteristics. One of two trained investigators administered the skin colour visual observation using the Munsell® skin colour charts and the code for one Munsell tile was recorded. A skin colorimeter was used to measure inner, upper arm skin colour. Three colorimeter measurements were taken for each participant and their average was recorded. The instrument was cleaned with a dry tissue between participants. Data were transferred from instrument output to standardised datasheets, each with the unique participant identifier code. Once sampling was

Table 1. Description of the measurement sites by building, type of space, type, intensity and colour of lighting per building.

Building number	Type of space	Description of lighting type	Light intensity (watts)	Lighting colour	Windows to the exterior
1	Canteen	Osram downlights	12	Warm white	Yes
2	Auditorium	Osram downlights and; panels of 3 Osram fluorescent tubes	12 15	Warm white Cool white	Yes
3	Auditorium	Panels of 3 Osram fluorescent tubes	15	Cool white	Yes
4	Canteen	Panels of 4 Osram fluorescent tubes	15	Cool white	Yes
5	Canteen	Panels of 3 Osram fluorescent tubes	15	Cool white	Yes
6	Auditorium	Osram downlights	12	Warm white	Yes
7	Meeting room	Panels of 3 Osram fluorescent tubes	15	Cool white	No
8	Canteen	Panels of 2 Osram fluorescent tubes	15	Warm white	Yes
9	Boardroom	Panels of 3 Osram fluorescent tubes	15	Cool white	Yes
10	Canteen	Standard Osram incandescent light bulb and Osram Energy saver globe	60 20	Warm white Cool white	Yes

complete, data were entered into a Microsoft Excel (2010) spreadsheet, before being imported into STATA 13.01 (StataCorp, 2013, Stata Statistical Software: Release 13, College Station, TX) and R 3.2.0 (The R Foundation for Statistical Computing, 2015). The study protocol was approved by the CSIR Researcher Ethics Committee (certificate number 79/2013).

Measures. Self-reported information was collected via a written questionnaire. Here, four variables derived from the questionnaire are reported: population group, gender, age and eye colour. Population group was defined according to the Statistics South Africa 2011 Census categories of Black, Indian/Asian, White, Coloured and Other. The other variables, not required for the present study, were reported in full elsewhere (8).

The Munsell® system is based on an atlas of colour represented in a three-dimensional expression by hue (relation to red, yellow, green, blue or purple), value (lightness) and chroma (strength) (11). The Munsell® colour tiles are on cards collated in a loose-leaf binder for ease of extraction and placement for skin colour assessment, using standard protocol for visual skin colour observation, as fully described elsewhere (7). The two trained investigators (MW and CYW), who administered the Munsell® classification, undertook an online test of their colour acuity (http://www.xrite.com/online-color-test-challenge), and both scored well within the acceptable score range for their age and gender. Colour options on four Munsell® cards (2.5YR, 5YR, 7.5YR and 10YR) were used to determine participants' natural skin colour. The assessments were made between 8h00 and 15h00 in indoor venues with artificial lighting and either with or without external windows (see Table 1). Each participant for a given venue sat on the same chair in the same location for the Munsell® colour assessment. The Munsell® colour (one tile's hue, value and chroma) observed for each participant's inner, upper arm was converted to an Individual Typology Angle (°ITA) value (see below for description of ITA) using supplementary data files reported elsewhere (4) which published ITA values for Munsell® colour tiles, as determined via spectrophotometry.

An Electronic GmbH Skin Colorimeter CL 400 WL (Courage+Khazaka, Germany) was used to objectively measure skin colour. This colorimeter has a core measuring area of 5 mm ø and an illuminated area of 17 mm ø with an accuracy of ± 5%. The colorimeter was calibrated each morning against a standard reference. Measurements were based on reflection of light from eight light-emitting diodes (LEDs) arranged circularly and for which the range of emitted wavelengths of light is 440-670 nm. L*a*b* index values are provided as output and the L* and b* values are converted immediately to °ITA scores calculated according to Del Bino (12) as:

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

Where L* is the difference along the lightness-darkness axis and b* is the difference along the yellow-blue axis. °ITA values can also be textually described where the higher the °ITA value the lighter the skin colour and vice versa (13). The colorimeter's measuring area was held against each participant's skin on their non-dominant inner upper arm. Three replicate measurements adjacent to each other were made and an average was calculated to determine a single °ITA value as an objective measure of constitutive skin colour.

Analysis. Munsell® assessed (subjective) and colorimeter measured (objective) skin colours were converted to continuous variables expressed as °ITA values. Linear regression was used to visually compare the two measures of skin colour. Since the data exhibited a monotonic distribution, Spearman's correlations were run to assess the relations between 1) Munsell® derived °ITA values and colorimeter °ITA values for all participants, and 2) Munsell® °ITA values and colorimeter °ITA values by participants measured in the same building for each of the ten buildings.

Results

Inner upper arm skin colour of 556 participants (267 male and 289 female) was assessed (Table 2). Most of the sample self-reported being Black (70.1%) with the remainder being either Indian/Asian (9.1%), White (17.8%) or Coloured (2.8%). More than two-thirds of participants reported being 26 to 45 years with dark brown eyes. Table 2 also shows the distribution of participants for population group, gender, age and skin colour according to the building number in which the participant's skin colour was assessed. These distributions were not analysed for statistical significance since differences in participants' characteristics by building would not influence the objective versus subjective skin colour measurements, which was the focus of this paper.

We compared Munsell® °ITA values and colorimeter °ITA values for all participants and found a strong positive, monotonic correlation (Spearman $\rho = 0.8585$, $p<0.001$) (Figure 1). Similar relationships were found for all ten buildings when Munsell® °ITA values and colorimeter °ITA values were compared by participants who were assessed in the same building (Figure 2) ranging from 0.797 (Building 4) to 0.934 (Building 3) , and all of these correlations were statistically significant ($p<0.001$).

Table 2. Percentage of participants for each census population group, gender, age and eye colour by building.

		Population group				Gender		Age						Eye colour				
Building	**Total (n)**	**Black (%)**	**Indian /Asian (%)**	**White (%)**	**Coloured (%)**	**Male (%)**	**Female (%)**	**18-25 years (%)**	**26-35 years (%)**	**36-45 years (%)**	**46-55 years (%)**	**56-65 years (%)**	**>65 years (%)**	**Light Blue, Grey or Green (%)**	**Blue, /Grey /Green (%)**	**Hazel or Light Brown (%)**	**Dark Brown (%)**	**Black (%)**
All	556	70.1	9.1	17.8	2.8	48.1	51.9	11.8	42.1	27.3	12.0	5.9	0.7	4.5	6.4	12.2	66.9	9.8
1	43	51.2	9.3	32.6	7.0	53.5	46.5	4.7	34.9	27.9	9.3	20.9	2.3	4.7	16.3	20.9	46.5	11.6
2	46	63.0	2.2	28.3	6.5	67.4	32.6	13.0	34.8	30.4	15.2	4.3	2.2	4.3	13.0	17.4	58.7	6.5
3	54	40.7	14.8	44.4	0.0	66.7	33.3	11.1	44.4	20.4	14.8	5.6	3.7	7.4	14.8	24.1	44.4	9.3
4	54	81.5	3.7	9.3	5.6	31.5	68.5	13.0	42.6	22.2	18.5	3.7	0.0	3.7	3.7	9.3	79.6	3.7
5	60	75.0	3.3	18.3	3.3	51.7	48.3	16.7	41.7	28.3	3.3	10.0	0.0	5.0	3.3	16.7	63.3	11.7
6	63	65.1	19.0	14.3	1.6	49.2	50.8	4.8	42.9	33.3	11.1	7.9	0.0	3.2	6.3	7.9	74.6	7.9
7	73	76.7	8.2	13.7	1.4	45.2	54.8	16.4	52.1	20.5	11.0	0.0	0.0	6.8	2.7	6.8	67.1	16.4
8	46	78.3	4.3	13.0	4.3	32.6	67.4	8.7	23.9	41.3	23.9	2.2	0.0	4.3	6.5	4.3	67.4	17.4
9	61	77.0	14.8	6.6	1.6	37.7	62.3	16.4	47.5	26.2	4.9	4.9	0.0	1.6	1.6	8.2	80.3	8.2
10	56	85.7	8.9	5.4	0.0	48.2	51.8	10.7	46.4	26.8	12.5	3.6	0.0	3.6	1.8	10.7	78.6	5.4

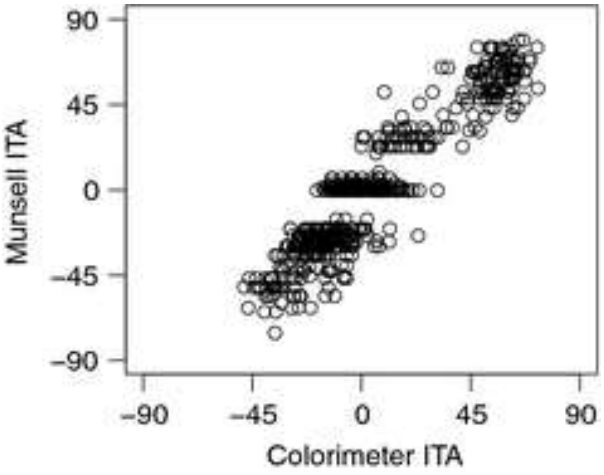

Figure 1. Correlation between Munsell °ITA versus Colorimeter °ITA for all participants' upper arm skin colour. Lower ITA values represent darker pigmented skin.

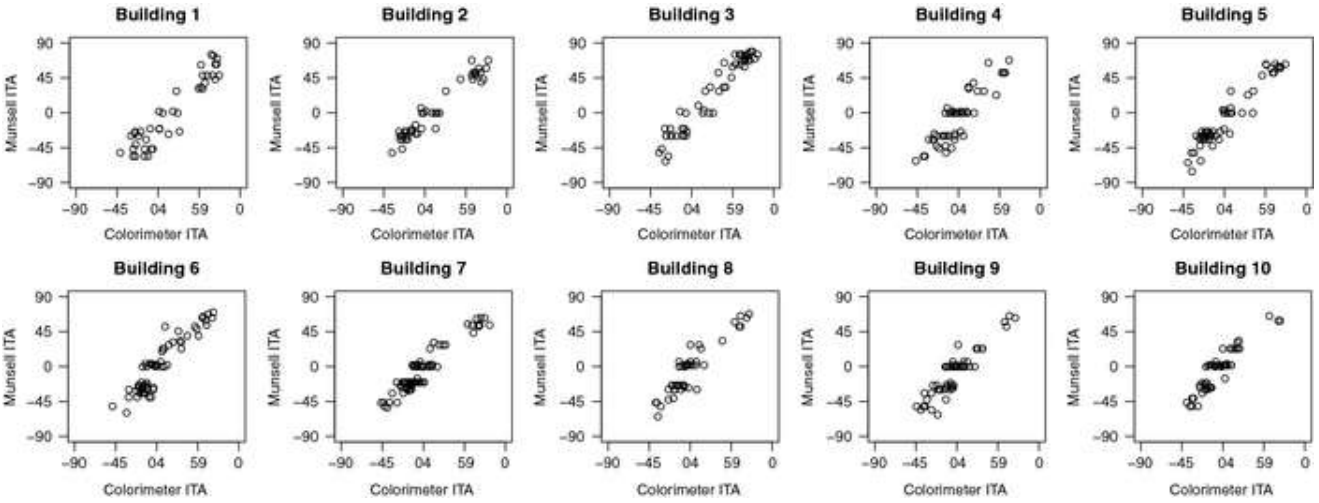

Figure 2. Correlation between Munsell °ITA versus Colorimeter °ITA for all participants' inner, upper arm skin colour by building where the participant was assessed. Lower °ITA values represent darker pigmented skin. Spearman ρ by building: Building 1, $\rho = 0.8585$; Building 2, $\rho = 0.869$; Building 3, $\rho = 0.934$; Building 4, $\rho = 0.797$; Building 5, $\rho = 0.808$; Building 6, $\rho = 0.810$; Building 7, $\rho = 0.893$; Building 8, $\rho = 0.893$; Building 9, $\rho = 0.809$; and Building10, $\rho = 0.894$ (all p values <0.001).

Discussion

The aim of this paper was to assess whether Munsell® skin colour measurements correlate with objective skin colour measurements in study venues with different lighting types and configurations. The comparison of Munsell® derived °ITA values and °ITA colorimeter values for all participants, not taking into account differences in study venue and lighting, showed excellent agreement between the two measures. This confirms the findings of earlier studies which found that Munsell® colour charts are valid and reliable tools for skin colour assessment in fieldwork contexts among tertiary

students (4) and primary schoolchildren (7). In developing countries where expensive equipment, such as a handheld spectrophotometer, may not be affordable and access to electricity may be sporadic, visual observation of skin colour, using a colour tool such as the Munsell® colour system, may assist epidemiologists and public health researchers to quickly assess skin colour with reasonable accuracy when such a measure is a necessary study parameter.

Similar findings were obtained when analyses were done separately by building. Regardless of differences in lighting types, configuration of lighting and mix of lighting types in a given study venue, Munsell® °ITA values correlated well with colorimeter °ITA values when compared for all participants who were assessed in the same building, and for all ten buildings. This was true for the observed range of °ITA skin colour values among participants in all population groups. Hence, even though there were different lighting situational settings in the different venues, visual observation of skin colour still correlated well with objective skin colour measurement. This suggests that so long as visual observations are made indoors with some form of artificial light (where there are no windows with natural light), assessment by a trained assessor may provide a measure of skin colour that correlates well with objectively measured skin colour.

Our findings provide support for the use of Munsell® colour charts for skin colour assessment in non-standardized, non-laboratory conditions that are typical for fieldwork settings. Notwithstanding this finding, it remains important to record information on lighting type and configuration should the need arise to consider results in relation to these factors, for example, where lighting type (e.g. wattage amount) differs substantially between assessment venues. Ease of assessment could be improved by having a flexible colour chart that bends to fit against the skin of the inner, upper arm. In our study, we were limited by the stiff, cardboard sheets forming part of the Munsell® Soil Colour Charts manual, and required that participants slightly bent their arm outward so that the skin on the inner, upper arm was more readily visible and accessible to the assessor.

Conclusion

We found it possible to visually assess skin colour in multiple situational lighting settings and retrieve results that compared well with objective measurements of skin colour. This was true for individuals of varying population groups and degrees of skin pigmentation.

Author contributions: Dr Wright and Mr Wilkes had full access to all of the data in the study and take responsibility for data integrity and accuracy of data analysis. *Study concept and design*: Dr(s)

Wright and Reeder. *Acquisition, analysis and interpretation of data*: Drs Wright and du Plessis, Mr Wilkes, Dr Reeder and Ms Albers. *Drafting of the manuscript*: Dr Wright. *Critical revision of the manuscript for important intellectual content*: Dr(s) Wright, Reeder, du Plessis, Mr Wilkes and Ms Albers. *Statistical analysis*: Dr Wright and Ms Albers. *Administrative, technical or material support*: Mrs Oosthuizen and Ms Nurse.

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