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Subjective and objective skin colour of a farmworker group in the Limpopo Province, South Africa

Short title:

Skin colour of a South African farmworker group

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Abstract:

Background: Farmworkers in the Limpopo Province, South Africa are at risk of excessive exposure to solar ultraviolet radiation (sUVR) due to both their work and the sUVR environment in the geographic area. However, the natural protection provided by this group's skin against sUVR has not been quantified. The aim of this study was to evaluate the subjective and objective skin colour of a group of farmworkers in order to classify the natural photoprotection provided by melanin and to evaluate the different measurement methods.

Materials and Methods: Skin colour was established by using the subjective Fitzpatrick Skin Phototype system (FST) questionnaire and two objective methods, namely the individual typology angle (ITA°) and melanin index (MI). A total of 71 farmworkers participated in the study.

Results: Black Africans tended to perceive their skin to be lighter than objectively measured, potentially due to cultural factors. The constitutive skin colour of most farmworkers were objectively classified in the FST V/brown group. Significant differences were found between the ITA° and MI of sun exposed (constitutive) and non-sun exposed (facultative) skin in Black African and White farmworkers. A strong correlation was found between ITA° and MI on different anatomical positions indicating both methods are appropriate to determine skin colour in deeply pigmented skin.

Conclusion: The evaluation of skin colour with the use of both subjective and objective methods may be used to design an effective photoprotection programme for farmworkers in the Limpopo Province.

KEYWORDS: farmworkers, skin colour, melanin index, individual typology angle, environmental health, sun exposure.

1. INTRODUCTION

The natural protection provided by the skin against the potentially harmful effects of exposure to solar ultraviolet radiation (sUVR) is genetically determined. This photoprotection is mainly provided by melanin found in skin[1], which acts as a protective barrier against sUVR reaching underlying structures of the skin including DNA[2]. The level of melanin does not necessarily stay constant after birth, with additional pigment synthesised in reaction to sUVR exposure to protect the skin[3].

The genetically determined level of protective melanin in an individual's skin is referred to as constitutive skin while skin that is exposed to sUVR is referred to facultative skin[4]. Increased melanin content of skin provides increased photoprotection but not absolute protection[5]. Damage to the DNA in the skin of individuals with elevated levels of melanin still occurs together with other negative health effects[6]. These health effects range from erythema to skin cancer.[7,8]

Several methods have been developed to classify skin in terms of the photoprotection it provides. These methods can be separated into subjective and objective methods[9]. The most often used subjective method is the Fitzpatrick Skin Phototype (FST) characterisation system[10]. This method uses self-report questions regarding the reaction of the skin to sUVR exposure and the development of freckles as well as questions on individual physical characteristics.[11] FST categories, I to VI, are defined based on constitutive characteristics pertaining to freckling, eye and hair colour as well as history of sunburn and tanning[11]. This method is easy to use which has added to its popularity[12]. However, it has been criticised as being prone to recall errors as well as subjected to the individual's own perception of their skin colour[13,14]. Some studies have also found that individuals with darker skin found the terminology such as tanning confusing leading to incorrect answers.[14,15]

Spectrometry has been found to be reliable in objectively measuring and classifying skin colour. However, the cost of equipment as well as training requirements may make this method impractical in some geographical locations.[9, 14] Measurements of individual typology angle (ITA°) and melanin content represent these spectrometry methods[14].

Environmental and behavioural factors influence the level of sUVR exposure of an individual[16]. Environmental factors include the higher ambient levels of sUVR found in geographical areas closer to the Equator and at higher altitude.[17] The most northern province of South Africa, the Limpopo Province, has a latitude of 23.39°S to 22.15°S and part of it falls in the area between the Equator and the Tropic of Capricorn.[18] Behavioural factors include the posture of the individual carrying out a specific activity. Different occupations perform different activities, leading to different sUVR exposures[19]. In general, outdoor workers receive higher levels of exposure to sUVR than indoor workers due to extended periods of working outdoors in the sun[20]. Occupations classified as being at high risk of exposure to sUVR includes working in the agricultural sector[21]. Although farmworkers in South Africa are at high risk of sUVR exposure due to both the environmental and behavioural factors mentioned, no study has been carried out to evaluate the natural photoprotection offered by the skin of this occupational group. Knowledge about the natural photoprotection of an occupational group can assist in the creation of customized photoprotection programmes. Although a study was carried out in an urban setting in South Africa on office workers to determine their skin colour, no study has been carried out in a rural setting at relatively high latitude and altitude in South Africa.[22]

This study aims to evaluate the subjective and objective skin colour of a group of farmworkers in the Limpopo Province of South Africa in order to classify the natural photoprotection of the farmworkers. The correlation of the subjective self-reported classification of skin colour and the two objective measurement methods is also reported.

2.MATERIALS AND METHODS

2.1 Study population

A total of 71 indoor and outdoor workers on an avocado and macadamia farm in the Soutpansberg mountains in the Limpopo province of South Africa were recruited (Figure 1). Ethical approval for the research study was provided by the North-West University Health Research Ethics Committee (ethics number: NWU-00101-17-A1). Data were collected after obtaining informed consent from the farmworkers.

2.2 Subjective classification of skin colour

Demographic information was collected from farmworkers including the population group with whom they identified. Farmworkers completed a simple questionnaire that consisted of six questions to determine their skin colour using the Fitzpatrick skin phototype classification. The questionnaire was available in Afrikaans, English, Tshivenda or Sepedi by an interpreter. Terminology that was unclear to farmworkers was explained in the farmworkers' choice of these four languages. No questions were used that referred to 'burning' or 'tanning' of the skin as other studies have found that these questions proved problematic in an ethnic diverse population as they did not fit into the culture [14,15]. The questions asked farmworkers to classify the colour of their eyes and hair, how many freckles they have and to choose the picture with the skin colour closest to their own.

2.3 Objective skin colour measurements

The individual typology angle (ITA°) and melanin index (MI) of the skin of farmworkers were measured using, a portable Courage+Khazaka Electronic GmbH Skin Colorimeter CL 400 WL and a Courage+Khazaka Electronic GmbH Mexameter® MX18, respectively. The instruments were calibrated and verified before measurements were taken. Measurements were taken in an indoor area where farmworkers could sit comfortably for 10-15 minutes before the measurements were taken. The skin colorimeter automatically calculated the ITA° from the measurements using the formula from Del Bino:

$ITA° = (ArcTangent(L-50)/b) \times (180/\pi)$ where π refers to the mathematical constant pi.

Skin colour was classified into the following categories using ITA°[23] :
Very light > 55° > Light > 41° > Intermediate > 28° > Tan > 10° > Brown > -30° > Dark

The MI, the quantification of the amount of melanin in the skin, was measured with the Mexameter®. Skin was classified into an FST group according to this index using the classification system adapted from the manufacturer's manual. This adapted system was chosen as it was specifically tailored to the South African context.[15]
FST I: 0-99.99; FST II: 100-149.9; FST III:150-249.9; FST IV: 250-349.9; FST V: 350-749.9; FST VI: >750

The back of the hand was chosen as the anatomical area that most accurately represented facultative skin colour while the inner upper arm was chosen to represent constitutive skin colour. The other anatomical positions were used to show distribution of skin colour. All anatomical positions measured are illustrated in Figure 2.

2.4 Data analysis

SPSS statistical software was used to perform statistical analyses with statistical significance indicated by $p \leq 0.05$. Descriptive statistics were used to describe results. The independent t-test was used to compare the means of ITA° or MI of the constitutive and facultative skin between the population groups, namely between Black African and White farmworkers as well

between the outdoor and indoor farmworkers. The means of all the anatomical positions in a population were compared using a repeated measures ANOVA with a Greenhouse-Geisser correction and a Bonferroni post hoc test. The correlation between the ITA° and MI on an anatomical site was established using the non-parametric Spearman correlation.

3. RESULTS

A total of 71 of the 74 farmworkers in the study were included in the analysis of the data. Of the 71 farmworkers, 22 (31%) were male and 49 (69%) were female. The farmworkers identified their population group as either Black African (86%) or White (14%) with no individual identifying themselves as Coloured (a South African population group term for individuals with mixed ancestry) or Indian/Asian. The farmworkers were also characterized as either outdoor or indoor farmworkers according to their job type.

There was also no statistical significant difference found between the ITA° ($F=1.98$, $p=0.17$) or MI ($F=1.53$, $p=0.20$) on the anatomical positions of the outdoor and indoor farmworkers. Therefore, the farmworkers were not evaluated further in terms of location of work/job type.

The self-reported FST**,** ITA° and MI classifications of the constitutive skin colour of Black African farmworkers are illustrated in Figure 3. The majority (62%) of Black African farmworkers reported their FST as either FST I, FST III or FST IV and only 5% reported it as FST VI. The most common classification of constitutive skin using the ITA° classification was brown (52%). The MI classification system also showed the same distribution with FST V (52%) being the most common classification of constitutive skin. The 38% of Black African farmworkers who reported that their skin fell in either the FST V or FST VI category was a lower percentage of the total Black African farmworker group than the 48% whose constitutive skin colour fell in either the brown or dark ITA ° categories and the FST V or FST VI groups according to MI.

Most White farmworkers (70%) classified their skin as FST II which was consistent with the objective skin colour classification according to both MI and ITA° classification systems (Figure 4). White farmworkers' constitutive skin colour ranged from very light to intermediate according to the ITA classification and FST I to FST III according to the MI classification.

The ITA° values among the White farmworkers were higher than for Black Africans ($F=519.56$, $p=0.00$). Figure 5 shows that the highest mean ITA°, and therefore lightest coloured skin, in the Black African farmworker group was found on the inner upper arm which was chosen to represent constitutive skin. Of the remaining five anatomical positions the lowest mean of ITA°, and thus darkest skin colour, was found on the back of the hand of Black African farmworkers which was chosen to represent facultative skin. The ITA° measured on anatomical positions in this farmworker group ranged from -66 to -5.

A repeated measures ANOVA with a Greenhouse-Geisser correction indicated that there were significant differences between the mean ITA° of the different anatomical positions ($F=56.21$, $p=0.00$). Post hoc tests using the Bonferroni correction showed that there were statistically significant differences in mean ITA° between the inner upper arm and the cheek ($p=0.00$). The ITA° on the back of the hand and dorsal forearm differed significantly from each other and with all other anatomical positons in the Black African farmworker group ($p=0.00$). Additionally, the forehead mean ITA° differed statistically significantly with that of the cheek ($p=0.04$). The ITA° on the anatomical positions in the White farmworker group ranged from -32 to 69. The highest mean ITA° was also found on the inner upper arm of in this farmworker group while the lowest mean ITA° was found on dorsal forearm. The mean ITA° measured on the anatomical positions of the White farmworkers differed significantly ($F=9.75$, $p=0.00$). Statistically significant differences in ITA° were found between the inner upper arm and the back of the hand ($p=0.02$), the cheek ($p=0.03$) and dorsal forearm ($p=0.01$).

The MI in the Black African farmworkers was generally higher than in White farmworkers (F=370.75, p=0.00). The mean MI provided in Figure 6 shows that the back of the hand was the anatomical site with the highest mean MI in the Black African group while the lowest MI and, thus, the lightest skin colour was found on the volar forearm. The MI measured on the anatomical sites ranged from 499 to 1 188.

In the Black African group, the repeated measures ANOVA with Greenhouse-Geisser correction showed statistically significant differences between the mean MI of the different anatomical positions (F=29.01, p=0.00). Statistically significant differences were found when both the dorsal forearm and the back of the hand were compared to all the other anatomical positions including each other, with p= 0.00 except for the comparison between the mean of the dorsal forearm and inner upper arm when p=0.01. The MI measured on the anatomical positions in the White farmworker group ranged from 70 to 529. The dorsal forearm was the anatomical site with the highest mean MI in White farmworkers while the lowest MI was found on the inner upper arm. The mean MI on the anatomical positions of the White farmworkers differed statistically significantly (F=16.08, p=0.00) (Figure 5). Significant differences were found for mean MI between the means of the dorsal forearm and the cheek (p=0.04), volar forearm (p=0.00) and inner upper arm (p=0.04) as well as between the volar forearm and both the cheek (p=0.01) and back of the hand (p=0.00).

A statistically significant strong negative correlation was found between the self-reported FST and constitutive (inner upper arm) ITA° of the Black African farmworkers (*p* = -0.775, p=0.000). However, no statistically significant correlation was found between the self-reported FST and constitutive (inner upper arm) ITA of White farmworkers (*p*= 0.229, p=0.553). The correlation between the self-reported FST and constitutive MI of Black African farmworkers was weak but still statistically significant (*p*=0.300, p=0.020). No statistically significant correlation was found between self-reported FST and constitutive MI of White farmworkers (*p*=-0.504, p= 0.166).

The strong significant negative correlation between the ITA and MI on the facultative (back of the hand) and constitutive skin (inner upper arm) is illustrated for Black African farmworker in Figure 7. The same strong significant negative correlation was found in the White farmworkers (Figure 8).

4. DISCUSSION

The unique demographic profile of workers in South Africa requires knowledge of the natural photoprotection of an occupational population to create an effective photoprotection programme for a specific workplace. The demographic profile of a workplace may influence the use of photoprotective measures that forms part of the programme and therefore its effectiveness[24,25]. This study found that more than 80% of the farmworkers identified themselves as Black African which is similar to the 2011 Census in which 97% of Limpopo province residents were Black African [26].

Even though there was a correlation between the self-reported (subjective) FST and both the ITA° and MI, most of the Black African farmworkers reported their skin colour being at least one FST category lighter than determined by objective measurements. It may be possible that some workers did not fully understand what was expected of them due to unfamiliar terms translated from English to Tshivenda or Sepedi. This potential confusion may explain the 15% of farmworkers that chose the FST I and FST II categories. However, it is unlikely that the 46% of workers who chose the FST IV category were confused when making their choice. This disparity between perceived and actual skin colour was also found in an urban South African work population which may indicate that it is a latent phenomenon that is not influenced by geographic area[22]. This tendency to consider their skin colour lighter than determined by

objective measurements may be an interesting mirror reflection of the so called 'dark shift' phenomenon identified by other studies[13]. Where the 'dark shift' phenomenon describes the overestimation of their skin melanin content by individuals with very fair skin, the current findings suggest that individuals with skin classified as brown or dark according to the ITA classification underestimated the melanin content of their skin. The perception that one's skin is lighter than it is in reality, may be due to the social norm that a lighter skin is more beautiful, illustrated by the popular practice of using skin lightening products by Black African women in South Africa[27]. Care should be taken that this underestimation of the skin melanin content of this occupational group does not lead to the perception that the use of photoprotection measures is unnecessary. It may only mean that the focus of a photoprotection programme needs to be shifted towards other photoprotective measures such as protection of the eyes.

The reason that no statistically significant differences were found between either the ITA° or MI of the anatomical positions of the outdoor and indoor farmworkers may be that the farmworkers are moved from one type of job to another according to what is needed on the farm as well as a high rate of seasonal workers. This means that a farmworker who is currently working as an indoor worker may have worked as an outdoor worker on the specific farm or another work site in the past, possibly recently. The variety in working conditions may have influenced their exposure to sUVR and, subsequently, their skin colour. The leisure activities of the outdoor and indoor farmworkers may also have been the same resulting in similar exposure to sUVR. These findings may indicate the ethnic group has a stronger effect on skin colour than job type on this specific occupational setting.

Both types of objective measurements of skin colour (ITA° and MI) determined that the constitutive skin colour of all Black African farmworkers fell in either the FST V/Brown or FST VI/Dark categories. This finding only partially agrees with previous research that found that the skin colour of most people born in South African falls in the range from FST I to V[15, 28]. While the majority of the farmworkers' constitutive skin colour did fall in this range, approximately 40% were classified as FST VI/Dark. This slight disparity may be due to a unique genetic makeup of individuals living in the farm's geographic area in the North of South Africa.

The significant differences that were found when comparing the skin colour of the majority of anatomical positions in both population groups as well when comparing the melanin content of skin in the Black African farmworkers may be due to how these positions varied in their sUVR exposure. This variation was expected as it was also reported in previous research done in the general population[22]. The variations in the skin colour in this farmworker population may be related to the different orientations of anatomical positions resulting from the specific body postures required by an activity. The different orientation resulted in different amounts of sUVR falling on each anatomical site[29]. For example, while bending forward to water a young sapling the cheek of the farmworker or farmer would be orientated mostly on the vertical plane and the sUVR possibly blocked by the head. In contrast, the dorsal forearm and back of the hand would be positioned on the horizontal plane and, therefore, receive more sUVR. The type of crops with which the farmworker or farmer works has an influence on the type of body posture that is adopted and protective clothing worn[30].

The significant difference found between the colour of the constitutive (inner upper arm) and facultative (back of the hand) skin may be explained by the reasons provided previously. Specifically, due to the reduced sUVR exposure of the inner upper arm caused by the wearing of shirts with sleeves and shielding of the inner upper arm by the arm structure. In contrast, the combination of the lack of wearing gloves by the farmworkers during work and the already mentioned orientation of the back of the hand may be the reason that this anatomical site was identified as having the darkest skin colour in the biggest population group namely Black African farmworkers. The significant difference between the constitutive (inner upper arm) and facultative skin (back of the hand) in the Black African population group (FST V to FST VI)

was also found in the White population group (FST I to FST III). Nevertheless, the small number of White farmworkers that participated in the study may have influenced the analyses with regards that specific population group.

A study that evaluated the mechanism of increased skin colour of individuals from different ethnic groups after irradiation with UVR found that the melanocyte density in Black skin was not elevated seven days after irradiation took place[32] This was in contrast to the melanocyte density in White and Asian skin which as slightly increased after the same time period[32] Regardless, the evidence that farmworkers whose skin colour was classified as FST I to FST III had 'tanned' to a greater extent than those farmworkers whose skin colour was classified as FST V or FST VI may indicate that the description that individuals in the darker FST categories (FST V and FST VI) "tanned profusely" is incorrect [33]. This flawed description of the tanning properties of the skin in these two phototypes may be that the first four original categories of the FST classification were determined using skin's clinical response to UVR exposure while the last two phototypes, that were added at a later stage, were determined using constitutive skin colour as well as ethnic classifications[34]. This finding may add to the growing argument for the expansion of the FST classification system by adding a category after FST VI to cater for the various skin types currently being grouped together in this last skin phototype category.

The strong significant correlations (all anatomical positions) between ITA° and MI resulted in the findings concurring with previous research that both objective measurements are suitable to determine skin colour in this type of population. [15] In addition, the ITA° skin colour categories have been found to correlate well with the MI FST categories, which further strengthens the finding that both systems may be used to objectively determine skin colour[31]. The choice of either of the two objective measurements of skin colour may make it easier to conduct these types of evaluations in rural areas where only one of the methods may be available. It is recommended that the adapted MI classification system, where the cut-off point of FST V was raised to 750, be used in a South African and possibly wider African context. Without the larger FST V classification group, the risk may arise that individuals with noticeably different skin colour are treated the same way when it comes to photoprotection.

This was the first study where the skin colour, and consequent natural photoprotection, of an agricultural occupational group was categorised in South Africa, specifically in the most northern province of the country. Several limitations of the study were identified. The first limitation was the small population of White farmworkers and the total lack of Coloured or Indian/Asian farmworkers due to the population demographic of the worker population on the farm. A larger sample would provide more accurate findings among White farmworkers as well as characterisation of the skin colour of the other two population groups. The second limitation is that it may not be possible to extrapolate this study's findings with regards to the profile of the skin colour and differences in the skin colour on the different anatomical positions to other farmworker populations in South Africa. This is due to the differences in the environmental and behavioural factors that influence workers' exposure to sUVR and, thus, their facultative skin colour. The genetic makeup of workers in other areas that influence their skin's response to sUVR may also be different. Similar studies should therefore be conducted in other occupations and geographical areas in South Africa. The third limitation is that the measurements were taken only during Summer. Facultative skin colour measurements may differ in other seasons as it is influenced by different sUVR levels received during these times. A follow up study to determine if facultative skin colour statistically differs in Winter would indicate if the previously reported seasonal variability of facultative skin is also found in this specific occupational population. A follow up study that extends over a few months will also indicated changes in skin colour and melanin content due to changes in work activities.

5. CONCLUSION

An effective photoprotection programme will need to cater to all skin phototype groups so that most farmworkers feel that the programme is relevant to them. In addition, extensive assessment of any photoprotection programme will be needed during pre-implementation to ensure that cultural beliefs and behaviours are carefully taken into consideration. Although self-reported FST is an appropriate method of determining skin colour, the cultural influences on the perception by the workers of their own skin colour should be taken into account when using the information in formulating photoprotective measures for the population. Both objective methods to determine skin colour was found to be appropriate to use in this population. The variation of skin colour on different anatomical positions should be also be used to inform the type of photoprotective measures that needs be focused on in the workplace. Overall, the evaluation of skin colour with the use of different methods is a valuable tool in the design of a successful photoprotection programme.

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CONFLICT OF INTEREST

None of the authors had a conflict of interest

REFERENCES

1. Swalwell H, Latimer R, Haywood RM, Birch-Machin M.A. Investigating the role of melanin in UVA/UVB-hydrogen peroxide induce cellular and mitochondrial ROSs production and mitochondrial DNA damage in human melanoma cells. Free Radic Biol Med. 2012; 52:626-634.
2. Juzeniene A, Moan J. Beneficial effects of UV radiation other than via vitamin D production. Dermato-Endocrinol. 2012; 4(2): 109-117.
3. Ravnbak MH. Objective determination of Fitzpatrick skin type. Dan Med Bull. 2015; 7(8), B4153.
4. Yamaguchi Y, Brenner M, Hearing V. The regulation of skin pigmentation. J Biol Chem. 2007; 282(38): 27557-27561.
5. Greinert R, De Vries E, Erdmann F, et al. European code against cancer 4th Edition: ultraviolet radiation and cancer. Cancer Epidemiol. 2015; 39 (Supplement 1): S75-S83.
6. Agbai ON, Buster K, Sanchez M, et al. Skin cancer and photoprotection in people of colour: A review and recommendations for physicians and the public. J Am Acad Dermatol.2014; 70(4):748-762.
7. Norval M, Cullen AP, De Gruijl FR, et al. 2007. The effects on human health from stratospheric ozone depletion and its interactions with climate change. Photochem Photobiol Sci. 2007; 6: 232-251.
8. Walterscheid JP, Nghiem DX, Kazimi N, et al. Cis-urocanic acid, a sunlight-induced immunosuppressive factor, activates immune suppression via the 5-HT2A receptor. Proceedings of the National Academy of Sciences. 2006; 103(46): 17420-17425.
9. Cestari T, Buster K. Photoprotection in specific populations: children and people of colour. J Am Acad Dermatol. 2017;76(3): S110-S121.
10. He SY, McCulloch CE, Boscardin WJ, Chen M, Linos E, Arron ST. Self-reported pigmentary phenotypes and race are significant but incomplete predictors of Fitzpatrick skin phototype in an ethnically diverse population. J Am Acad Dermatol. 2017; 71(4): 731-737
11. Fitzpatrick TB. The validity and practicality of sun-reactive skin type I through VI. Arc Dermatol.1988;124: 869-871.
12. Park S, Huh C, Choe Y, Young J. Time course of ultraviolet-induced skin reactions evaluated by two different reflectance spectrophotometers: DermaSpectrophotometer© and Minolta spectrophotometer CM-2002©. Photodermatol Photoimmunol Photomed. 2002 ;e18: 23-28.

13. Reeder AI, Hammond VA, Gray AR. Questionnaire items to assess skin colour and erythemal sensitivity: reliability, validity, and the “dark shift”. Cancer Epidemiol Biomarkers Prev. 2010; 19: 1167-1173.
14. Eilers S, Bach DQ, Gaber R, et al. Accuracy of self-report in assessing Fitzpatrick skin phototypes I through VI. JAMA Dermatol. 2013; 149(11):1289-1294.
15. Wilkes M, Wright CY, Du Plessis JL, Reeder A. Fitzpatrick skin type, individual typology angle, and melanin index in an African population: steps toward universally applicable skin photosensitivity assessments. JAMA Dermatol. 2015; 151(8): 902-903.
16. Milon A, Sottas P, Builliar JL, Vernez D. Effective exposure to solar UV in building workers: influence of local and individual factors. J Expo Sci Environ Epidemiol; 2007; 17: 58-68.
17. Corrêa MP. Solar ultraviolet radiation: properties, characteristics and amount observed in Brazil and South America. An Bras Dermatol; 2015; 90(3): 297-313.
18. Google Maps. Limpopo province, South Africa. https://www.google.com/maps/place/Limpopo/@-23.7526466,26.9005949,7z/data=!3m1!4b1!4m !3m4!1s0x1ec6c91436cd30c1:0x62893d1e66c8dc4a!8m2!3d-23.4012946!4d29.4179324. 2019. Accessed March 27, 2019.
19. Nardini G, Neri D, Paroncini M. Measured anatomical distribution of solar UVR on strawberry production workers in Italy. J Agric Saf Health. 2014; 20(2): 67-78.
20. ICNIRP. Protecting workers from ultraviolet radiation. https://www.icnirp.org/cms/upload/publications/ICNIRPUVWorkers.pdf. 2010. Accessed March 28, 2019.
21. Peters CE, Nicol AM, Demers PA. Prevalence of exposure to solar ultraviolet radiation (UVR) on the job in Canada. Can J Public Health. 2012;103(3):223-226.
22. Wright CY, Wilkes M, Du Plessis JL, Reeder AI. Self-reported skin colour and erythema sensitivity vs. objectively measured constitutive skin colour in an African population with predominantly dark skin. Photodermatol Photoimmunol Photomed. 2015, 31:315-524.
23. Del Bino S, Sok, J, Bessac E, Bernerd F. Relationship between skin response to ultraviolet exposure and skin colour. Pigment Cell Res. 2006; 19(6): 606-614.
24. Houdmont J, Davis S, Griffiths A. Sun safety knowledge and practice in UK postal delivery workers. Occup Med. 2016; 66:279-284.

25. Gies P, Glanz K, O'Riordan, D, Elliot T, Nehl E. Measured occupational solar UVR exposures of lifeguards in pool settings. Am J Ind Med. 2009; 52(8):645-653.
26. STATSSA (Statistics South Africa). Census 2011 – provincial profile: Limpopo. http://www.statssa.gov.za/publications/Report-03-01-78/Report-03-01-782011.pdf. . 2014. Accessed March 29 2019.
27. Dlova NC, Hamed SH, Tsoka-Gwegwani J and Grobler A. Skin lightening practices: an epidemiological study of South African women of African and Indian ancestries. Br J Dermatol. 2014; 175(Suppl 2): 2-9.
28. Karsten AE, Singh A, Karsten PA, Braun MWH. Diffuse reflectance spectroscopy as a tool to measure the absorptive coefficient in skin: South African skin phototypes. Photochem Photobiol. 2013; 89: 227-233.
29. Nardini G, Neri D, Paroncini M. Higher body anatomical distribution of solar ultraviolet radiation on farm workers. WSEAS Transactions on Environment and Development. 2014; 10(0): 256-263.
30. Salas R, Mayer JA, Hoerster KD. Sun-protective behaviours of California farmworkers. JOEM. 2005; 47(12): 244-1249.
31. Choe YB, Jang SJ, Jo SJ, Ahn KJ, Youn JI. The difference between the constitutive and facultative skin color does not reflect skin phototype in Asian skin. Skin Res and Technol. 2006;12: 68-72.
32. Tadokoro T, Yamaguchi Y, Batzer J et al. mechanisms of skin tanning in different racial/ethnic groups in response to ultraviolet radiation. J Invest Dermatol. 2005; 124: 1326-1332.
33. Lopez S, Smith-Zubiaga I, Garcia de Galdeno AG, Boyano MD, García O, Gardeazábal J, et al. Melanocytes from dark and light skinned individuals under basal conditions and following ultraviolet-B irradiation, PLoS ONE. 2015; 10(8);e0134911.doi.10.1371/journal.pone.0134911.
34. Del Bino S, Duval C, Bernerd F. Clinical and biological characterization of skin pigmentation diversity and its consequences on UV impact. Int J Mol Sci. 2018; 19(2668): doi:10.3390/ijms19092668.

FIGURES

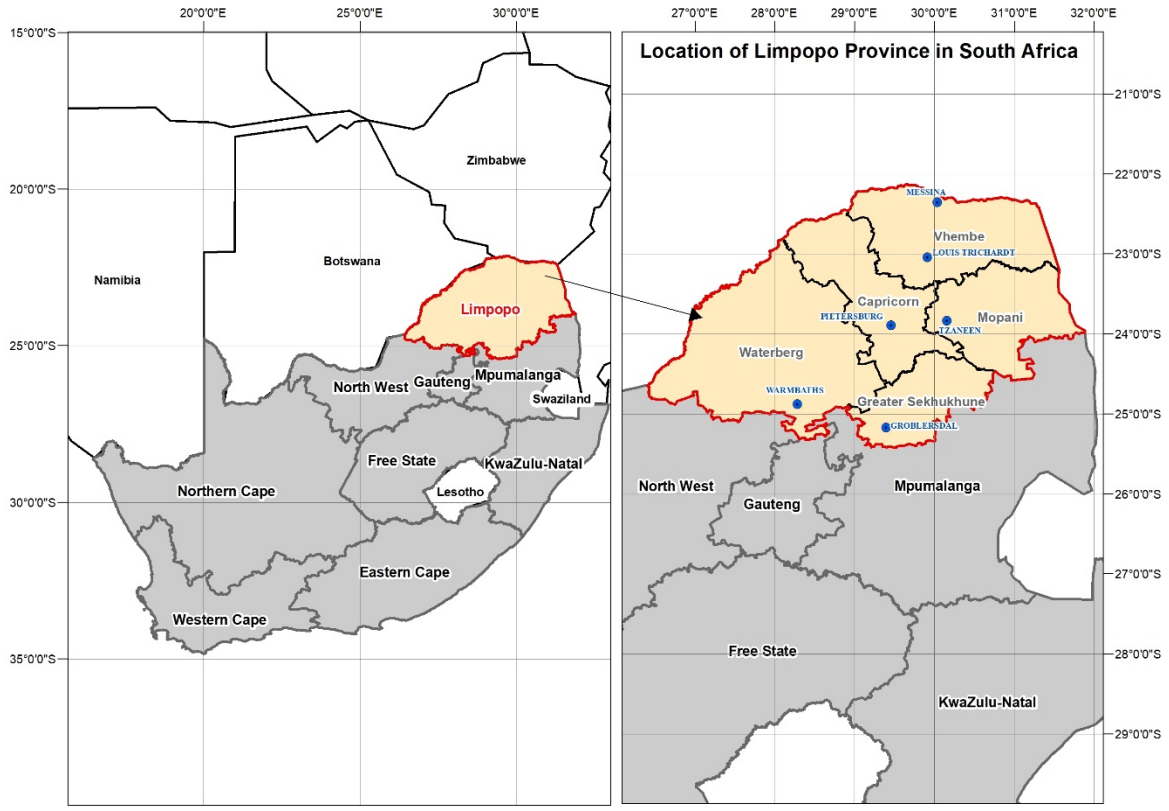

Figure 1. Location of the study site within South Africa.

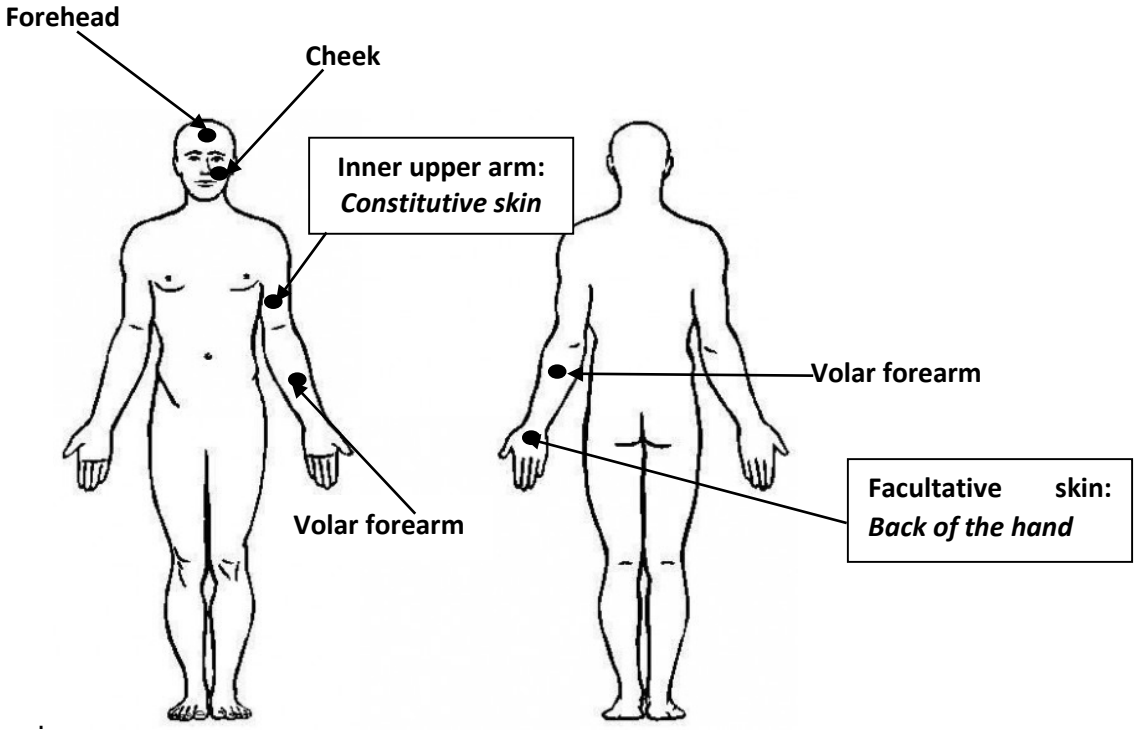

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Figure 2: Location different anatomical measurement positions (adapted from clipart from pervis-spann.com).

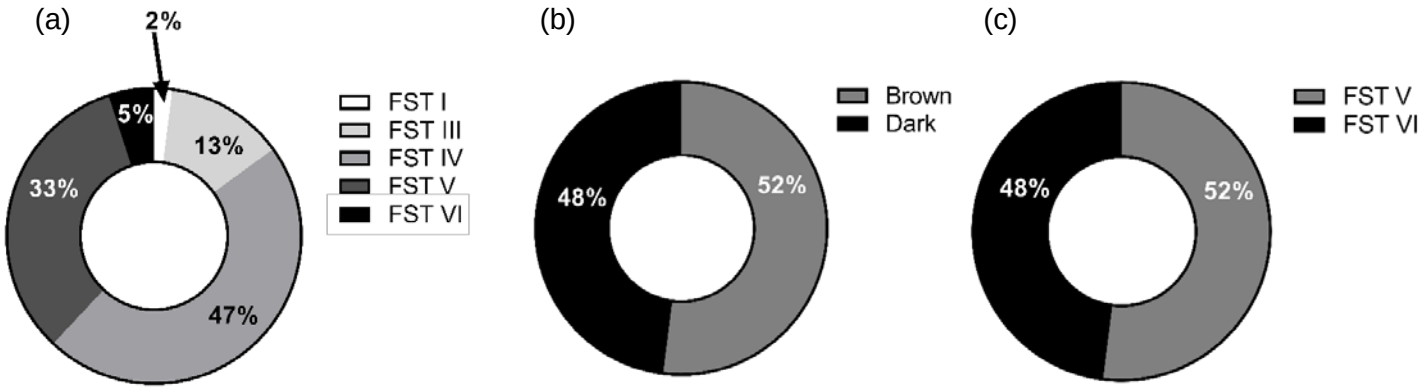

Figure 3: (a)The self-reported (subjective), (b) ITA° and (c) MI classification of constitutive skin colour of Black African farmworkers.

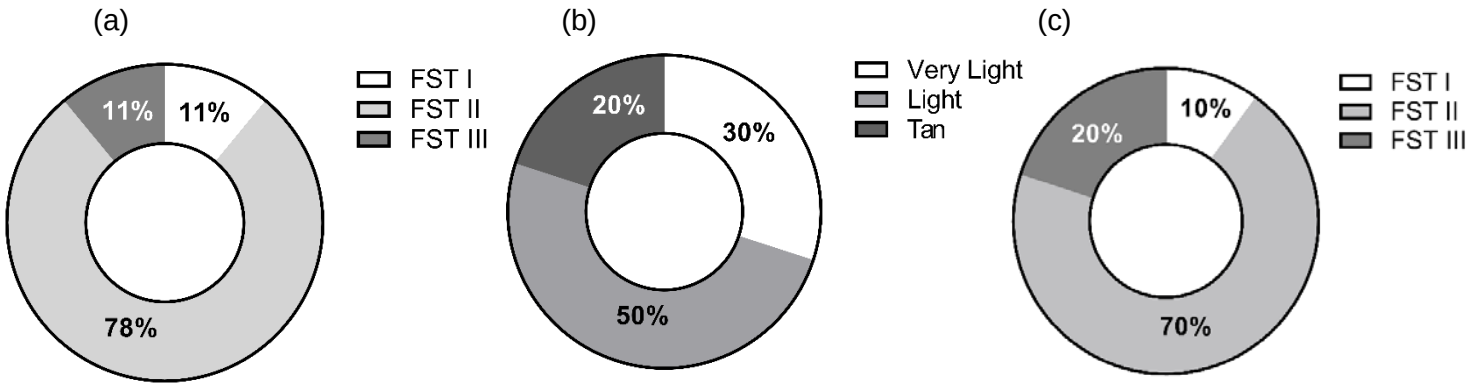

Figure 4: (a) The self-reported (subjective), (b) ITA° and (c) MI classification of constitutive skin colour of White farmworkers

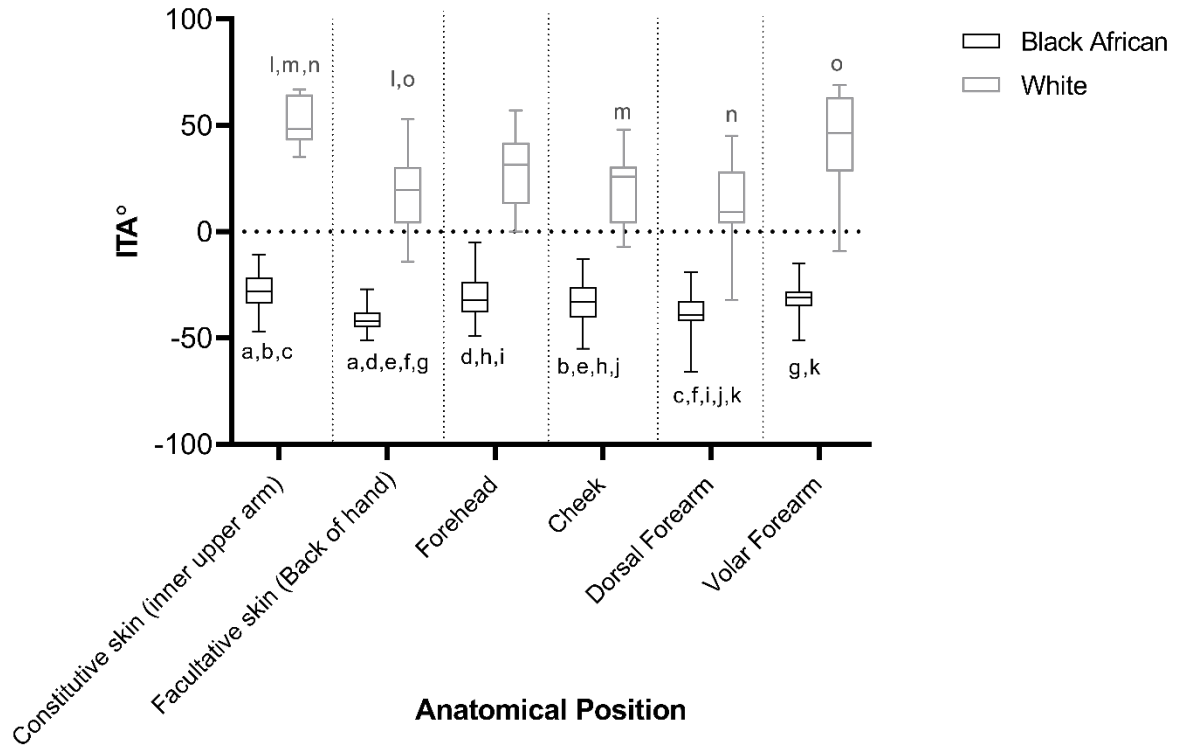

Figure 5: The statistically significant differences between ITA° values on anatomical positions of Black African and White farmworkers. The line in the middle of the box section of the graph indicates the mean ITA°. The box extends from the 25th to the 75th percentile with upper limit indicating the maximum ITA° and lower limit indicating the minimum ITA°. The alphabet letters indicate the anatomical positions as determined by repeated measures ANOVA.

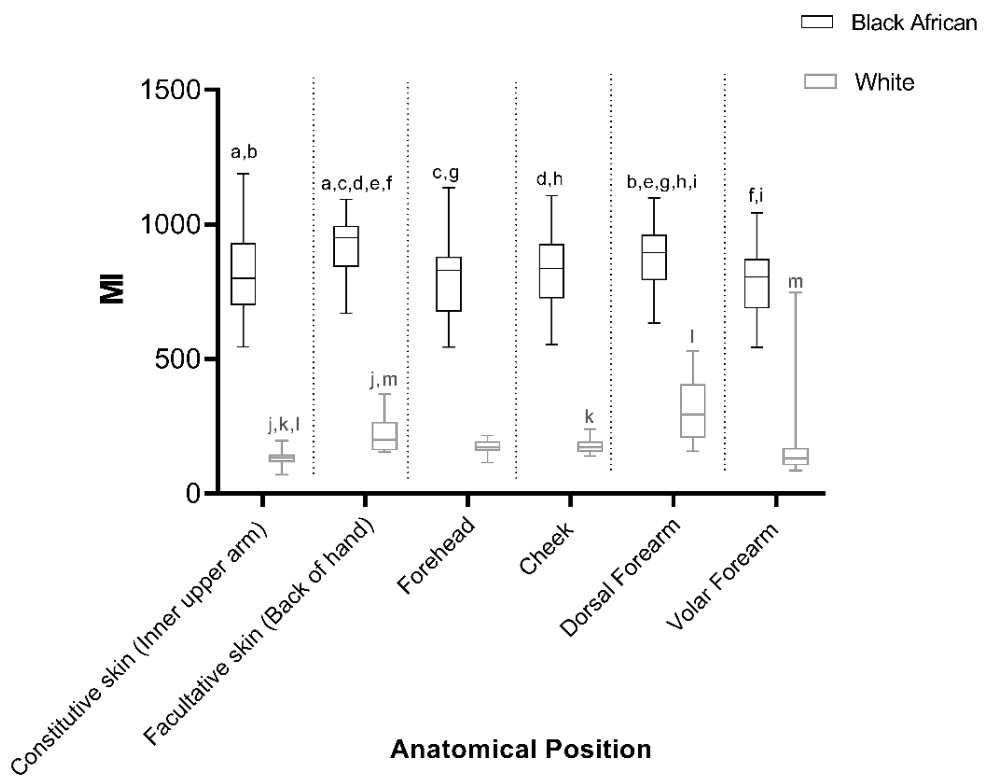

Figure 6: The statistically significant differences found between MI values on anatomical positions of Black African and White farmworkers. The line in the middle of the box section of the graph indicates the mean MI. The box extends from the 25th to the 75th percentile with upper limit indicating the maximum MI and lower limit indicating the minimum MI. The alphabet letters indicate the anatomical positions as determined by repeated measures ANOVA

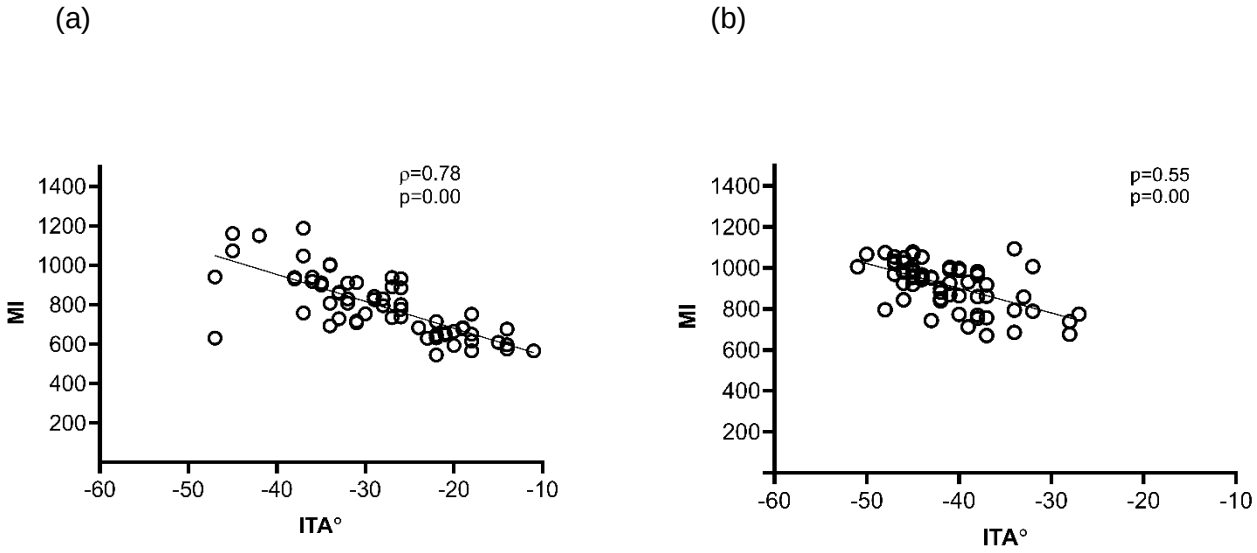

Figure 7: Correlation between the ITA° and MI in the Black African farmworker population group on the (a) constitutive skin (inner upper arm and (b) facultative skin (back of the hand)

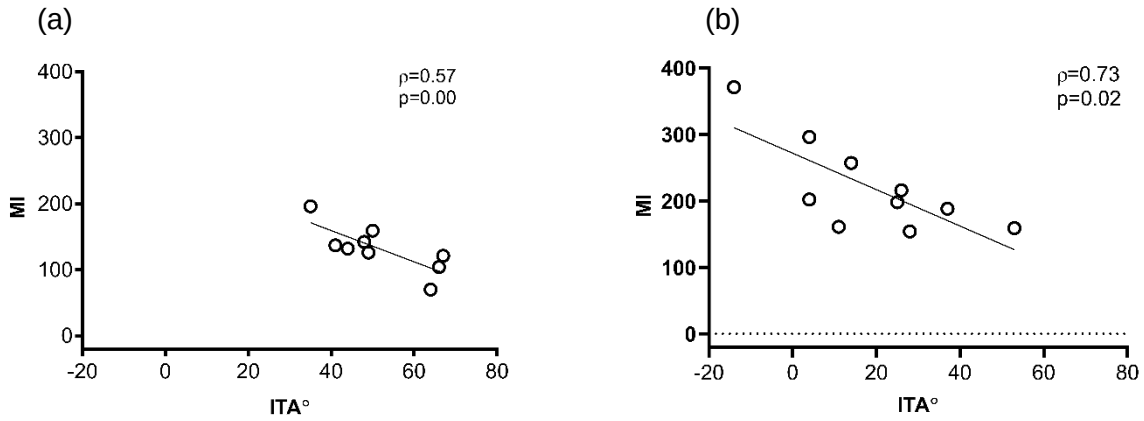

Figure 8: Correlation between the ITA° and MI in the White farmworker population group on the (a) constitutive skin (inner upper arm) and (b) facultative skin (back of the hand)