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Are the Fitzpatrick Skin Phototypes Valid for Cancer Risk Assessment in a Racially and Ethnically Diverse Sample of Women?

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The Fitzpatrick Skin Phototypes (FSP) were developed to classify skin color and response to ultraviolet radiation. FSP are used clinically to assess risk for sunburn and skin cancer. Our aim was to determine the criterion-related validity of self-reported FSP when compared with skin color and sunburn history, controlling for age, race/ethnicity, and seasonality/geography. We performed a secondary analysis of data (N=466) from an observational study. The racial/ethnic composition of the sample was 45% White/White Hispanic (WWH), 40% Black/Black Hispanic (BBH), and 15% Other Identities. Outcome measures were self-reported FSP and sunburn history, as well as physiological measures of skin color (L* lightness/darkness, a* redness/greenness, b* yellowness/blueness). Correlation between FSP and L* was -.77 (95% CI -.81, -.73; P<.001). Although 60% of the variance in FSP was accounted for by L* values for the entire sample, only 5% of the variance was accounted for among BBH participants (r=-.23), and up to 30% for WWH/Other Identity participants (r=-.48 and -.52). Multiple regression analysis indicated L* and b* values, sunburn history, and race/ethnicity, but not geography/seasonality or a* values significantly and collectively accounted for 72% of the variance in FSP. While the criterion validity of FSP was established by the strong relationship between L* values and FSP for the entire sample, when examined at the level of individual racial/ethnic subgroups, criterion validity of FSP was not demonstrated. When self-reported FSP are used for clinical skin assessment and sun cancer screening, they provide a restricted range of options for people with darker skin that does not capture variations in their skin color. Inaccuracy of clinical data may lead to unequal treatment or inadequate cancer risk assessment. *Ethn Dis*. 2019;29(3):505-512; doi:10.18865/ed.29.3.505

Introduction

The Fitzpatrick Skin Phototypes (FSP) were developed in 1975 to classify skin color, or complexion, and the skin's response to ultraviolet radiation (UVR).[1] Fitzpatrick created FSP to determine the appropriate dose of ultraviolet A for people with 'fair' skin undergoing treatment for psoriasis.[2] Because fair-skinned persons were having phototoxic reactions from UVR therapy when classified by hair and eye color alone, Fitzpatrick added UVR skin tolerance to create the FSP. People's self-reported response to three, 45 to 60 minutes of sun exposure at 12 noon during summer months in Boston, Massachusetts was defined as the 'minimum erythema dose,' or MED. Skin of the Type I phototype (pale skin, blue eyes, and fair hair) was defined as burning and peeling easily with sunburn lasting for several days after MED.[2] Skin of the Type IV phototype (light brown skin, brown eyes, and brown hair) was defined as not burning at 24 hours and having a good tan at seven days after MED. Fitzpatrick designated Types II and III as the intermediate classifications between Types I and IV.[2] In 1986 Fitzpatrick added people with brown (Type V) and black (Type VI) skin into the classification.[3]

While no initial validity testing for FSP occurred, confidence in the construct validity was supported by studies with primarily non-Hispanic White participants. In a study of 22 participants with Type II, III, and IV phototypes, the MED response and FSP had a linear relationship.[4] When using FSP to determine the dosage for

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UVR to treat psoriasis in multi-center studies, only 2%-3% of participants either failed to improve or needed to stop treatment.[2] Conversely, others found no significant correlations between MED and FSP in White students (N=790).[5] These findings raised questions about the validity of the FSP as a self-report instrument, although FSP are cited as the gold standard in skin type classification.[6,7]

Recently, data have accumulated on the validity of self-reported FSP for multi-racial/ethnic populations. Studying a group of Mexican American (n = 337) and Puerto Rican (n = 13) participants, researchers found that FSP ranged from Types I to V, with 42.3% reporting Type II. The FSP and melanin index (derived measure of epidermal melanin content, where high melanin content is associated with dark skin) had a significant correlation (Spearman r=.88, P<.01).[8] In a study of 270 non-Hispanic White, Hispanic, Black, and Asian/Pacific Islander participants, self-reported responses to tanning questions could not be classified using standard FSP definitions, and measures of melanin were significantly different from FSP for Types III, IV, V, and VI.[9] In another group of 3,386 multiracial, Black, Asian, non-Hispanic White, Hispanic, and Native American participants, investigators found that there were significant limitations to using patient-reported race/ethnicity and skin appearance in predicting sunburn risk.[7] In a randomly selected Black/African American group (N = 2,085) from California, 59% of participants were unable to classify themselves using the FSP (they selected the response ‘none of the above describes me’).[10] In a population-based sample (N=2,656), investigators found that the FSP correlated moderately well with sun sensitivity in non-Hispanic White (*r*=.35, P<.001) and Mexican Hispanic (*r*=.27, P<.001), but not in non-Hispanic Black participants (*r*=.09, P= .03).[11]

The FSP may not be sensitive to racial/ethnic differences in sun exposure responses and behaviors. Agbai and colleagues note that people of color are commonly categorized into FSP IV to VI, but their skin colors span the entire spectrum of phototypes and do not always match the FSP categoris.[12] Epidemiology studies report that the highest sunburn prevalence occurs in non-Hispanic White and Native American participants.[13] Non-Hispanic Whites have higher rates of sunscreen use than Hispanics and non-Hispanic Blacks,[12,14] and several investigators suggest that people of color do not perceive the need to use sun protection.[10,14,15]

These studies raise questions about the validity of self-reported FSP, particularly for people with darker skin tones. Initial work to develop the FSP focused primarily on non-Hispanic Whites[2-5] and used error-prone measures of skin color (self-report or color schematics)[5,7,9] One study used the spectrographic readings of melanin index to determine skin color in a diverse sample,[9] but questions exist about the validity of the melanin index (a derived variable) in people with dark skin.[16] Further work is needed to determine the appropriateness of the FSP in all people using rigorous methods such as spectrophotometry to determine constitutive (untanned) skin color.

Our primary aim was to determine the criterion-related validity of self-reported FSP when compared with constitutive skin color and sunburn history among racially and ethnically diverse women from the United States and Puerto Rico. We also determined the association of FSP and sunburn history, when controlling for age, race/ethnicity, and seasonality/geography.

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Methods

We performed a secondary analysis of data collected from a community-based English and Spanish-speaking women aged [3] ≥21 years (N=446) living in Philadelphia and San Juan. Participants were enrolled in a prospective study comparing skin injury in women following consensual sexual intercourse to a database of injuries that occur after sexual assault. We have not included data from the sexual assault registry in this article. Skin color and FSP were used to determine if injury detection varied by skin tone. The primary study included an interview, a forensic gynecologic examination after consensual intercourse (data not included in this article), and skin color measurements. Men were not included in the study because, while both women and men can be assaulted, sexual assault is a significant problem for women.[17,18] Data for the primary study were collected between November 11, 2008 to January 15, 2014. Secondary data analysis was completed in February 2018.

Participants were recruited with flyers distributed at health sciences centers and were screened by phone to determine whether they met inclusion criteria. Women who had injury to the genitalia were excluded. We screened 575 and enrolled 466 women; 109 women declined to participate. The research was approved by the affiliated universities' institutional review boards (IRB) and all procedures followed were in accordance with the ethical standards of the IRB and the Helsinki Declaration of 1975, as revised in 2000. Study procedures were explained to potential participants by study personnel in English or Spanish and participants received $50 for screening and $150 for the interview, examination, and skin measurements.

Sampling Procedures

In order to obtain a representative sample, we recruited women who matched the age and race/ethnicity of cases in an existing sexual assault registry (N>1,000 cases): 1) the proportion of cases in various age categories (21-24, 25-34, 35-44, 45-54, 55-64, ≥ 65 years old) and race/ethnicity categories were determined from the registry; 2) the projected sample size for the current study was distributed across the age categories; and 3) as given categories were filled, participants matching on their age and race/ethnicity were excluded.

Fitzpatrick Skin Phototype

Trained research assistants interviewed participants for 10 minutes using either an English- or Spanish-language interview guide at the skin research laboratory. The following statement was read to them: "Your skin type is determined by several different factors. One of these factors is genetics, as indicated by skin color and reaction to sun exposure. Please choose one of the following descriptions of your skin." Participants were asked to rate their skin as one of the six skin types: Type I, very fair, always burns, never tans; Type II, fair, burns easily; Type III, fair, sometimes burns; Type IV, beige-olive, burns minimally; Type V, moderate brown, rarely burns; Type VI, dark brown or black, never burns[1-3,19]

Spectrophotometric Measurement of Skin Color

We conceptualized skin color using a commonly accepted color space (1976 CIELAB [CIE L*a*b*]), a three dimensional model that represents colors relative to a white reference point[20,21] and calculates the mathematical difference between colors.[22-24] It consists of three axes at right angles: L* axis represents the light/dark component, a* axis represents the red/green component, and b* axis represents the yellow/blue component. Skin L* values generally range between 20 (dark) and 85 (light).[21,24] Skin redness (a*) values range from +1 to +30, and skin yellowness (b*) values range from +5 to +40.[24] For this study, measurements were made with a reflectance spectrophotometer (ColorTec® PSM, Clinton, NJ), considered the gold standard for skin color measurement.[25,26] We chose the inner upper arm, two inches distal from the axilla, as the site for measurement because it is considered protected from sun exposure.[24,27,28] Quality control procedures ensured that L* values had no more than +/- 5% error.

Sunburn History, Seasonality/Geography, and Demographics

Trained research staff asked participants: "In the past 12 months, how many times did you have a red, blistering, or painful sunburn that lasted a day or more?" Responses were recoded as experiencing or not experiencing any sunburn within the last 12 months. Because a portion of our participants were enrolled in Puerto Rico, we considered that this subset of our sample had increased likelihood of experiencing sunburn regardless of the season. Therefore seasonality/geography was a single variable that indicated the participant was either from Puerto Rico or assessed between May 1 and September 30 during the summer season in Philadelphia. To determine age, research staff asked participants: "What is your date of birth?" To determine race/ethnicity, research staff asked participants to choose the best response among the following categories: Asian; African American/

Black not of Hispanic origin; African American/Black of Hispanic origin; White, not of Hispanic origin; White of Hispanic origin; Native American; Biracial/Multiracial; and Other.

Analysis

Means, standard deviation, and percentages were calculated (Table 1) for all study variables as a function of the FSP. Chi-square (categorical) and ANOVA (continuous) were used to compare the distributions of study variables across FSP. Upper arm L* values and FSP were compared across racial/ethnic groups (White/White Hispanic [WWH]; Black/Black Hispanic [BBH], Other Identity) using 1-way ANOVAs, followed by post-hoc *t*-tests when the omnibus *F*-statistic was significant. Sunburn in the last year and seasonality/geography were compared across racial/ethnic groups using Chi-square tests. Two independent samples *t*-tests were used to compare L* values between sunburn groups as well as between seasonality/geography groups. The criterion-related validity of self-reported FSP scores was assessed 1) for all study participants, and then by racial/ethnic group, by correlating FSP scores with upper arm L* values; and 2) for the entire sample, in a multivariate linear regression model with FSP as the outcome and upper arm L*, a*, and b* values, as well as sunburn history, seasonality/geography, and race/ethnicity as predictors, and adjusting for age. Regression diagnostics did not show any significant departures from the assumptions of this analytical approach. An alpha of ≤.05 was used in all statistical tests. All analyses were conducted using R.[29]

Results

Data from 446 women were available for analysis. Forty-five percent of participants identified themselves as WWH, 40% identified themselves as BBH, and 15% stated that they had Other Identities. Participants who chose Other Identity used the following self-descriptors: Trigueña (term used in Puerto Rico to mean not Black, not White, n=23); bi- or multi-racial (n=20); Latina (n=13); Asian American (n=3); and other identities based on a geographical location (n=9). The average age of the study group was 32.8 (SD=9.9). Twenty four percent indicated that they experienced a sunburn within the past 12 months (n=107). Prevalence of sunburn history varied significantly across racial/ethnic groups, with WWH participants reporting a significantly higher prevalence of sunburn in the last 12 months (35.7%) than both Other Identity (26.7%) and BBH (4.8%) participants (both P<.001). Although 52.8% of all participants were from Puerto Rico or were enrolled during months with higher sun exposure (May to September), this percentage varied significantly across racial/ethnic groups ($X2[2] = 20.0$, P<.001): 64.2% BBH, 55.9%

Table 1. Descriptive statistics for study variables by FSP scores (N=446)

	FSP Score						
Variable	**1**	**2**	**3**	**4**	**5**	**6**	**P**
Total study group, % (n)	4.7 (21)	12.1 (54)	32.1 (143)	12.1 (54)	8.5 (36)	30.9 (138)	<.0001
Race/ethnicity, % (n)							<.0001
BBH	0 (0)	2.2 (4)	12.2 (22)	5.0 (9)	8.33 (15)	71.1 (128)	
OI	0 (0)	2.9 (2)	33.8 (23)	22.1 (15)	27.9 (19)	13.2 (9)	
WWH	10.4 (21)	23.9 (48)	48.8 (98)	14.9 (30)	0.9 (2)	0.5 (1)	
Age	31.6 (7.9)	31.2 (8.7)	32.1 (9.0)	32.1 (11.2)	31.0 (9.0)	35.0 (10.8)	.059
L* value	68.0 (2.5)	65.1 (6.0)	60.3 (8.5)	57.3 (10.1)	51.1 (8.6)	42.8 (5.8)	<.0001
a* value	6.57 (1.26)	7.12 (1.46)	8.25 (1.54)	8.83 (1.50)	9.64 (1.17)	10.16 (0.92)	<.0001
b* value	14.95 (2.51)	17.37 (2.56)	19.11 (2.63)	19.34 (2.47)	21.25 (2.49)	19.84 (2.48)	<.0001
Summer-enrolled or PR sample, % (n)	2.6 (6)	7.7 (18)	31.2 (73)	10.7 (25)	10.3 (24)	37.6 (88)	<.0001
Any sunburn in last 12 months, % (n)	12.7 (9)	23.9 (17)	38.0 (27)	15.5 (11)	5.6 (4)	4.2 (3)	<.0001

FSP, Fitzpatrick Skin Prototypes; BHH: Black/Black Hispanic; WWH: White/White Hispanic; OI: Other Identity
Values are M (SD) or % (n) row-wise.
Ps are from omnibus ANOVA (continuous) and Chi-square (categorical) tests.

Other Identity, and 41.4% WWH.

The average FSP score for all participants was 4.00 (SD=1.60). FSP scores varied significantly across racial/ethnic groups ($F[2,443] = 647.80$, P<.001) with BBH participants having a significantly higher score (M=5.4, SD=1.2) than both WWH (M=2.7, SD=.9) and Other Identity (M=4.2, SD=1.1) participants, and Other Identity participants having significantly higher scores than WWH participants (all P<.001) (Table 1).

Upper arm L* values significantly differed across racial/ethnic groups, with L* values for WWH participants being significantly higher (lighter) than for Other Identity and BBH participants (both P<.001) and also Other Identity participants being significantly higher than BBH participants (P<.001). Additionally, participants with a sunburn in the past 12 months had a significantly higher upper arm L* value (M=6361.9, SD=484.5) as compared with those who did not (M=5197.3, SD=1206.4) (t[170.16]=10.06, P<.001). Upper arm L* values were lower (darker) among those from Puerto Rico or those enrolled during high sun exposure months (M=4922.6, SD=1119.1) as compared with those not from Puerto Rico or enrolled during low sun exposure months (M=5788.8, SD=1058.4) (t[338.5]=7.58,P<.001).

Table 2. Multiple regression analysis of FSP scores as a function of upper arm skin color values, sunburn history, seasonality/geography, racial/ethnic group, and age, N=446

	B	SE	t	P
Intercept	6.022	.865	6.96	<.001
Age, years	-.002	.006	-.34	.736
BBH vs OI	-.611	.229	-2.68	.008
BBH vs WWH	-1.372	.271	-4.90	<.001
Upper arm L* value	-.001	.001	-4.80	<.001
Upper arm a* value	-.003	.001	-.64	.523
Upper arm b* value	.001	.0002	4.79	<.001
Seasonality/Geography	.057	.127	.45	.654
Sunburn in last 12 months	-.285	.096	-2.98	.003

SE, standard error; t, t-statistic; FSP, Fitzpatrick Skin Phototype; BBH, Black/Black Hispanic; WWH, White/White Hispanic; OI, other identity.
Model $R2 = .72$, adjusted $R2 = .71$.

Criterion-related Validity of FSP Scores

Although the correlations between the L* values and FSP were high for the entire group, when stratified by race/ethnicity the relationships between the two measures became fairly weak, even though statistically significant. Up to 60% of the variance in FSP scores were accounted for by upper arm L* values for the entire sample (r=-0.77 [95% CI -.81, -.73], P<.001). However, approximately 5% of the variance in FSP scores was explained by upper arm L* values for BBH participants (r=-.23 [95% CI -.37, -.08], P=.003) and up to 30% of the variance for WWH and Other Identity participants (r=-.48 [95% CI -.59, -.35], P<.001 and -.52 [95% CI -.71, -.27], P<.001, respectively).

Results of the multivariate model showed that FSP scores were significantly predicted by upper arm L* and b* values, sunburn history, and race/ethnicity, but not geography/seasonality (Table 2). There was an inverse relationship between upper arm L* values and FSP scores such that higher upper arm L* values corresponded to lower FSP scores (P<.001). Higher b* values (higher yellowness values) were significantly associated with higher FSP scores (P<.001). Participants with a history of sunburn in the last 12 months had significantly lower FSP score than those without a sunburn (P=.003). For instance, the mean FSP score for participants with a sunburn in the past 12 months was 2.9 (SD=1.2) and for those without the mean was 4.2 (SD=1.5) (t[144.26] = 7.14, P<.001). Similar to what was reported above from the univariable analyses, BBH participants had higher FSP scores than both WWH (P<.001) and Other Identity (P=.008) participants. Collectively, the variables included in the statistical model accounted for over 70% of the variation in FSP scores ($R^2 = 72.2$).

Discussion

Aspects of the validity of FSP were supported by our findings. The multiple regression analysis from our total sample provided support for validity by demonstrating that skin L* and b* values, sunburn history, and race/ethnicity significantly and collectively accounted for 72% of the variance in FSP scores. In contrast, the FSP did not function well when applied to specific racial/ethnic subgroups. Only 5% of the variance in FSP scores was explained by L* values in the BBH sample, raising serious questions about the validity of the FSP for people of color. We suggest that the descriptors for FSP skin types V and VI may not be appropriate for BBH individuals. Agbai and colleagues note that while people of color are commonly categorized into FSP IV to VI by the FSP definitions, their skin colors span the entire spectrum of FSP from I to VI.[12]

Several investigators have found significant limitations using self-reported skin appearance, sunburn history/risk, and FSP in people who self-identified as BBH or African American.[7,10] Notably, 59% of African American participants in one study (N=2,085) indicated that they were unable to classify themselves using the FSP.[10] In another study of non-Hispanic White, non-Hispanic Black, Hispanic, and Asian participants, 42% (114 of 270) of participants' responses about skin color, burning, and tanning did not fit the FSP. A portion of non-Hispanic Black participants stated they did not tan (term used in the FSP), but rather their skin got darker. The investigators concluded that difficulties with self-reported FSP were related to the interpretation of the subjective terms, sunburn and tan.[9] Other studies reflect similar problems with the FSP. In a sample of 556 people in South Africa, 96.8% reported that sun affected their skin, regardless of their FSP category. Of the 390 Black African participants, 95.6% described themselves as photosensitive. The authors suggested that FSP VI should only be used for people with no photosensitivity regardless of skin color.[30]

If the gold standard instrument for classifying skin color and sun exposure (FSP) is not a valid measure for people of color, health disparities may follow.

If the gold standard instrument for classifying skin color and sun exposure (FSP) is not a valid measure for people of color, health disparities may follow. While several skin cancers occur 10 times more often in White as compared with Black/African American individuals, Black/African Americans have poorer prognoses and survival rates.[14,15] Skin assessment instruments such as the FSP are often used in conjunction with patient counseling about skin protection. If people are classified incorrectly, they may be less likely to institute skin protective measures.

Our findings point to several avenues for future research. Language describing sun exposure must match people's experiences and skin responses. Sunburning and tanning are not universal descriptors. While Eilers and colleagues have proposed a skin classification system for people of color,[9] the recommendations have not undergone validity testing and do not appear to be derived from participant interviews. Exploring the opinions of BBH individuals about descriptors of sun exposure appropriate to a phototype classification system is warranted to refine instruments.

Skin color measurement systems other than FSP have problems with accuracy as well. Authors from South Africa suggest that the algorithms used to derive melanin density (MD), a derived spectrophotometric variable, were obtained from data collected from Caucasians and do not predict biopsy melanin concentrations in Black African participants.[16] Ongoing refinement of skin color measures is important not only for assessing skin response and determining cancer risk, but also to facilitate skin injury detection.[31] Technological innovation to measure skin color and the skin's sun response accurately will advance skin science. Until that time, instruments that measure skin color through spectrophotometry may be a better choice than derived measures.

This study was limited by our choice to organize the data by the three race/ethnicity categories based on self-report. Additional measures of skin color, such as melanin index or MD, were not used in this protocol, although concerns exist about the validity of derived measures.[16] In spite of quality control, instrument bias may have occurred during skin color measurement. Selection bias may have occurred from our representative sample. Response bias, interviewer bias, and/or social desirability bias may have occurred during collection of self-reported data.

The choice of an all-female sample is both a strength and limitation.

Our findings provide new information about relationship between skin color and sun exposure in women, and the validity of the FSP in females. Because sun exposure is higher in males, and use of sun protection measures with sunscreen is lower in males than females,[13] men have a higher risk of sun-related damage. Future work needs to include both men and women, consider men's and women's language concerning sun exposure, and have adequate sample sizes to make gender comparisons.

Finally, the initial work on the FSP by Fitzpatrick and his colleagues was completed in Boston, Massachusetts by measuring MED.[2] The response to sun exposure at latitudes differing from Boston may not be comparable to Fitzpatrick's preliminary work.[2] The strength and directness of the sun's rays change by latitude, and therefore the MED may vary by latitude. In spite of the international use of the FSP as the gold standard,[6,7,19] the categories designed by Fitzpatrick may not be appropriate to participants studied in other geographical regions and during other seasons of the year.

Conclusions

The FSP remains the most commonly used strategy to assess skin color and skin sensitivity to UVR. Our data raise serious questions about the validity of the FSP. Skin color measurements with a spectrophotometer did not correlate well with FSP categories, particularly for BBH participants. Because FSP are used for clinical skin assessment and sun cancer screening, patients and practitioners may not recognize cancer risk or the need for protective measures from sun exposure if the information is not valid for all people. Inaccurate clinical data will result in continuation of health disparities in skin assessment. We suggest that skin color measurements be separated from sun exposure during patient assessment because people do not fit neatly into the FSP. Practitioners can then determine risk for people based on each parameter and develop an individual cancer prevention strategy to promote health.

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Conflict of Interest

No conflicts of interest to report.

Author Contributions

Research concept and design: Sommers, Fargo, Brown, Perfetti, Margolis; Acquisition of data: Sommers, Fargo, Regueira, Brown, Everett; Data analysis and interpretation: Sommers, Fargo, Beacham, Margolis; Manuscript draft: Sommers, Fargo, Beacham, Perfetti, Everett; Statistical expertise: Fargo, Margolis; Acquisition of funding: Sommers, Fargo; Administrative: Sommers, Regueira, Beacham, Perfetti, Everett; Supervision: Sommers, Regueira, Brown

References

1. Fitzpatrick T. Soleil et peau [Sun and skin]. *Journal de Medecine Esthetique.* 1975;2:33-34.
2. Fitzpatrick TB. The validity and practicality of sun-reactive skin types I through VI. *Arch Dermatol*. 1988;124(6):869-871. https://doi.org/10.1001/archderm.1988.01670060015008 PMID:3377516
3. Fitzpatrick TB. Ultraviolet-induced pigmentary changes: benefits and hazards. *Curr Probl Dermatol*. 1986;15:25-38. https://doi.org/10.1159/000412090 PMID:3512179
4. Pathak MA, Fanselow DL. Photobiology of melanin pigmentation: dose/response of skin to sunlight and its contents. *J Am Acad Dermatol*. 1983;9(5):724-733. https://doi.org/10.1016/S0190-9622(83)70186-6 PMID:6358278
5. Rampen FH, Fleuren BA, de Boo TM, Lemmens WA. Unreliability of self-reported burning tendency and tanning ability. *Arch Dermatol*. 1988;124(6):885-888. https://doi.org/10.1001/archderm.1988.01670060031011 PMID:3377517
6. Roberts WE. Skin type classification systems old and new. *Dermatol Clin*. 2009;27(4):529-533, viii. viii. https://doi.org/10.1016/j.det.2009.08.006 PMID:19850202
7. He SY, McCulloch CE, Boscardin WJ, Chren MM, 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*. 2014;71(4):731-737. https://doi.org/10.1016/j.jaad.2014.05.023 PMID:24928709
8. Robinson JK, Penedo FJ, Hay JL, Jablonski NG. Recognizing Latinos' range of skin pigment and phototypes to enhance skin cancer prevention. *Pigment Cell Melanoma Res*. 2017;30(5):488-492. https://doi.org/10.1111/pcmr.12598 PMID:28504868
9. 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. https://doi.org/10.1001/jamadermatol.2013.6101 PMID:24048361
10. Pichon LC, Landrine H, Corral I, Hao Y, Mayer JA, Hoerster KD. Measuring skin cancer risk in African Americans: is the Fitzpatrick Skin Type Classification Scale culturally sensitive? *Ethn Dis*. 2010;20(2):174-179. PMID:20503899
11. Keiser E, Linos E, Kanzler M, Lee W, Sainani KL, Tang JY. Reliability and prevalence of digital image skin types in the United States: results from National Health and Nutrition Examination Survey 2003-2004. *J Am Acad Dermatol*. 2012;66(1):163-165. https://doi.org/10.1016/j.jaad.2011.02.044 PMID:22177642
12. Agbai ON, Buster K, Sanchez M, et al. Skin cancer and photoprotection in people of color: a review and recommendations for physicians and the public. *J Am Acad Dermatol*. 2014;70(4):748-762. https://doi.org/10.1016/j.jaad.2013.11.038 PMID:24485530
13. Buller DB, Cokkinides V, Hall HI, et al. Prevalence of sunburn, sun protection, and indoor tanning behaviors among Americans: review from national surveys and case studies of 3 states. *J Am Acad Dermatol*. 2011;65(5)(suppl 1):S114-S123. https://doi.org/10.1016/j.jaad.2011.05.033 PMID:22018060
14. Buchanan Lunsford N, Berktold J, Holman

DM, Stein K, Prempeh A, Yerkes A. Skin cancer knowledge, awareness, beliefs and preventive behaviors among Black and Hispanic men and women. *Prev Med Rep*. 2018;12:203-209. https://doi.org/10.1016/j.pmedr.2018.09.017 PMID:30364862

15. Pichon LC, Corral I, Landrine H, Mayer JA, Norman GJ. Sun-protection behaviors among African Americans. *Am J Prev Med*. 2010;38(3):288-295. https://doi.org/10.1016/j.amepre.2009.10.041 PMID:20171530
16. Wright CY, Lucas RM, du Plessis JL, Kapwata T, Kunene Z. Towards a reliable, non-invasive melanin assessment for pigmented skin. *Skin Res Technol*. 2019;25(1):100-102. PMID:29790599
17. Mellins CA, Walsh K, Sarvet AL, et al. Sexual assault incidents among college undergraduates: prevalence and factors associated with risk. *PLoS One*. 2017;12(11):e0186471. https://doi.org/10.1371/journal.pone.0186471 PMID:29117226
18. Zijlstra E, Esselink G, Moors ML, LoFo-Wong S, Hutschemaekers G, Lagro-Janssen A. Vulnerability and revictimization: victim characteristics in a Dutch assault center. *J Forensic Leg Med*. 2017;52:199-207. https://doi.org/10.1016/j.jflm.2017.08.003 PMID:28961551
19. Sachdeva S. Fitzpatrick skin typing: applications in dermatology. *Indian J Dermatol Venereol Leprol*. 2009;75(1):93-96. https://doi.org/10.4103/0378-6323.45238 PMID:19172048
20. Fairchild MD. *Color appearance models*. Hoboken, NJ: Wiley; 2005.
21. Chardon A, Cretois I, Hourseau C. Skin colour typology and suntanning pathways. *Int J Cosmet Sci*. 1991;13(4):191-208. https://doi.org/10.1111/j.1467-2494.1991.tb00561.x PMID:19291061
22. Reinhard E, Khan E, Oguz Akyuz A, Johnson G. *Color imaging: Fundamentals and applications*. Wellesley, MA: A.K. Peters, Ltd; 2008. https://doi.org/10.1201/b10637
23. Ha S, Lee M, Lee O, et al. A study of a method for distribution analysis of skin color. *Skin Res Technol*. 2009;15(2):200-213. https://doi.org/10.1111/j.1600-0846.2009.00355.x PMID:19416467
24. Sommers M, Beacham B, Baker R, Fargo J. Intra- and inter-rater reliability of digital image analysis for skin color measurement. *Skin Res Technol*. 2013;19(4):484-491. https://doi.org/10.1111/srt.12072 PMID:23551208
25. Takiwaki H. Measurement of skin color: practical application and theoretical considerations. *J Med Invest*. 1998;44(3-4):121-126. PMID:9597799
26. Takiwaki H, Miyaoka Y, Arase S. Analysis of the absorbance spectra of skin lesions as a helpful tool for detection of major pathophysiological changes. *Skin Res Technol*. 2004;10(2):130-135. https://doi.org/10.1111/j.1600-0846.2004.00063.x PMID:15059181
27. Alaluf S, Atkins D, Barrett K, Blount M, Carter N, Heath A. The impact of epidermal melanin on objective measurements of human skin colour. *Pigment Cell Res*. 2002;15(2):119-126. https://doi.org/10.1034/j.1600-0749.2002.1o072.x PMID:11936269
28. Parra EJ, Kittles RA, Shriver MD. Implications of correlations between skin color and genetic ancestry for biomedical research. *Nat Genet*. 2004;36(11)(suppl):S54-S60. https://doi.org/10.1038/ng1440 PMID:15508005
29. *Team RDC: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing; 2012.
30. 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. https://doi.org/10.1001/jamadermatol.2015.0351 PMID:25923982
31. Sommers MS, Zink TM, Fargo JD, et al. Forensic sexual assault examination and genital injury: is skin color a source of health disparity? *Am J Emerg Med*. 2008;26(8):857-866. https://doi.org/10.1016/j.ajem.2007.11.025 PMID:18926341