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Sun damage in ultraviolet photographs correlates with phenotypic melanoma risk factors in 12-year-old children

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INTRODUCTION

The incidence rate for melanoma has risen faster than any other cancer in the United States for the past several decades.¹ Among women aged 25–29 years, melanoma is currently the most common malignancy.² Risk factors for melanoma include a personal or family history of the disease, skin phototype, race/ethnicity, phenotypic characteristics such as skin, hair and eye color, density of freckles, presence of multiple nevi and sun exposure.^{3–5} Of these, sun exposure is the main preventable risk factor.⁴ Recommended prevention strategies include avoiding mid-day sun, wearing protective clothing, staying in the shade, avoiding tanning beds and wearing sunscreen. While these strategies have been widely promoted, sun protection campaigns have not been successful in changing sun exposure trends or mitigating melanoma rates.^{1,6} The lack of success of these recommendations suggests other

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approaches, including individualized interventions targeting those at high risk may be warranted.

Ultraviolet (UV) photography creates an individualized means of discussing the risks of sun exposure and promoting sun safety. Highlighting current individual damage on the participant's face is particularly effective compared to less specific educational efforts.⁷⁻¹⁴ When combined with information explaining the role of sun exposure in photoaging, UV photography has helped reduce college students' intentions to tan, actual tanning behavior and measured skin tan (using a colorimeter) as much as one year post intervention.^{7,11} The intervention has also been shown to reduce sunburns in Middle school students aged 11-13 years old with many facial freckles two and six months post intervention.¹⁴ While sun exposure is often motivated by a belief that tanning improves appearance, this intervention capitalizes on the role of sun light in causing wrinkles, mottled pigmentation, skin laxity, atrophy, elastosis and telangiectasias.¹⁵ The photographs make sun damage immediately apparent before it is otherwise discernible.¹⁶

UV photographs are an excellent means to display sun damage in the form of mottled pigmentation because UV light is attenuated by melanin.¹⁷ Recently, a computer software algorithm that produces a score assessing sun damage captured in UV, cross-polarized and visible photographs was developed.¹⁸ Dark spots on UV photographs indicate sun damage, with more and larger spots indicating greater damage (see Figure 1). In children and adolescents, one form of mottled pigmentation is freckling, a temporary pigmentary characteristic and an important melanoma risk factor.⁵

To our knowledge, only one study has evaluated the relationship between melanoma risk factors with the severity of sun damage shown in UV photographs.¹⁹ That study, which examined eight children between 2 and 12 years old, found that the sun damage shown in UV photographs was greater in older children with skin phototypes I and II, and increased one year later in two of the eight children. While it is clear that viewing UV photographs can increase children's awareness of sun damage, lead to increased sun protection and likely lead to a decreased risk for melanoma, the question of whether UV photographs of children with a higher phenotypic risk for melanoma show more severe sun damage remains unanswered. In the present study, we hypothesized that the severity of sun damage captured by UV, cross-polarized and standard visible photographs of children correlates with phenotypic melanoma risk factors.

METHODS

Study Design and Sample

This study was reviewed and approved by the Colorado Multiple Institutional Review Board (Protocol No. 96-014) and by the Institutional Review Board of Kaiser Permanente of Colorado (Protocol No. CO-10-1430). The children who participated in this study were part of a cohort of 1,145 children born from January 1998 to September 1998 described previously.²⁰⁻²² All children were 11 or 12 years old at the time of examination. Skin examinations and recording of photographs and scores were performed from July through September 2010. Of the 625 children who participated in skin exam sessions in 2010, 620 (99%) provided consent to have their photographs and scores recorded. Of these, photographs and scores were recorded for 609 (98%) and stored for 585 (94%). Time constraints prohibited the proper recording of photographs and scores for 11 children, and technical difficulties involving the transfer of the digitally stored photographs and scores from the camera to our secure server resulted in the loss of data for 24 children.

Recording of Photographs and Scores

Children were asked not to wear sunscreen, makeup or moisturizer the day their photographs were taken. They were asked to pull back their hair with a single use hair band, remove all jewelry from the face and neck, and to spend one minute cleaning their faces with a soap-based wipe. Children with brightly colored shirts were given a black shirt cover to minimize reflection from the clothing. Full-face frontal view photographs of each child were recorded using a VISIA™ Version 4.0c Facial Complexion Analysis System (Canfield Scientific Inc, Fairfield, NJ).

The system includes xenon tubes that produce a standard visible flash. For the UV photographs, glass UV filters placed in front of the light source produced a 365 nm peak wavelength. For the visible photographs, no filters were used. For the cross-polarized photographs, the system placed perpendicularly oriented polarizing filters in front of the light source and the camera. The purpose of the polarizing filters was to block reflected light from the skin, allowing only absorbed and re-emitted light to be detected by the camera. The photographs were recorded with a Canon Powershot S80 digital camera set to the superfine image capture setting, yielding images with a resolution of 400 pixels per inch. Automatic focus and a pre-set white balance correction delivered reproducible photographs. For the UV photographs, an aperture of $f/4.0$, ISO of 100, shutter speed of 1/60 and white balance set to daylight were used. For the cross-polarized photographs an aperture of $f/8.0$, ISO of 50, shutter speed of 1/100 and white balance set to daylight were used. For the visible photographs, an aperture of $f/5.6$, ISO of 100, and shutter speed of 1/60 and white balance set to fluorescent were used.

The cross-polarized images were processed using VISIA™ 5.2 software to produce separate brown- and red-component images separating the brown- and red-colored light absorbed and re-emitted by the skin.¹⁸ Scores quantifying sun damage in the brown-component image and separately in the red-component image were then produced. These scores are hereafter referred to as the “brown” score and “red” score. A mask delineating the area of analysis on the face was drawn by the software and adjusted by the camera operator to include the forehead, nose and cheeks and exclude the eyes and facial hair (see Figure 1). For each of the UV, visible, brown and red photographs, spots were defined as areas of skin meeting a threshold level of color contrast to adjacent skin. The VISIA™ software then produced separate UV, visible, brown and red scores quantifying the percent area of the face comprised by the spots in each of the photographs.

Due to a manufacturer reported variability of 5%,²³ we recorded three successive sets of photographs and scores for each child for the first 231 children. After reviewing the photographs and scores for these children, we found that some of the variability of successive photographs of the same child could be explained by the varied quality of the mask defining the area of analysis on the face. Specifically, the VISIA™ software recorded some darkly colored facial hair as spots for some children, leading to higher scores. We therefore modified the protocol such that only one to two rounds of photographs and scores were recorded for each child, and the operator was allowed extra time to carefully adjust the mask to exclude facial hair.

Skin Examinations

A team consisting of a dermatologist, a pediatrician, a medical student and 7 pediatric nurses conducted skin examinations. The skin team documented full body melanocytic nevus counts for the full body, but excluding the buttocks, genitals, scalp and breast area for girls. Compound and dermal nevi were differentiated from freckles and café-au-lait spots when they were raised. Junctional nevi were identified by their dark brown color, regular borders

and lack of occurrence in patches. Congenital nevi were excluded by history. The number and location of nevi were recorded on a body map. All examiners participated in at least one duplicate examination, and the interrater reliability coefficient ($n = 86$) was 0.90.

Eye color charts aided in the assessment of eye color, and samples of dyed hair aided in determining hair color.^{21,24} Facial freckling was assessed relative to a diagram of various freckling densities on the face corresponding to a scale of 0-100, incrementing by 10, in which lower numbers indicated less freckling. Constitutive skin coloration was recorded using a Chroma Meter CR-400 colorimeter (Konica Minolta Sensing, Inc, Osaka, Japan). We used the mean of five L scale readings taken at a point 7.5 cm below the child's axilla on their inner arm in the analysis.^{21,25-26}

Data Analysis

Visible, UV, Brown, and Red scores served as the outcome variables in the primary analyses. For the purposes of these analyses, hair color designations were classified as red, blonde, blondish brown to light brown, medium to dark brown, and black. Eye color was classified as blue, green or hazel, or brown. Facial freckling scores, which also exhibited a positive skew, were grouped as none (0), low (10-30), or medium to high (40-100). Children with high facial freckling levels were relatively uncommon, so they were combined with the medium freckling level group. Skin coloration scores were dichotomized into light skin color (L scale ≥ 60) and other skin color (L scale < 60). This cut-off has been used in previous studies.^{20,27-28} Total nevus counts were trichotomized, based on a one-third split of the observed distribution, as shown in Table 1. To further explore associations between nevi and scores on each outcome variable, total nevi counts were separated into counts of nevi on the face and counts of nevi on all examined body parts except the face. Scores on both of the measures were trichotomized as described above. We first calculated the visible, UV, brown and red score observed (untransformed and unadjusted) means and standard deviations for each group.

To correct for a large positive skew, scores on each outcome variable were subjected to a logit transformation, which converts the score proportion into the natural logarithm of the proportion divided by 1 minus the proportion, prior to analysis. Since zero values cannot be used in logit transformations, 10^{-5} , a value that was smaller than our smallest nonzero datum, was added to zero values prior to the transformation. In one set of analyses, Analysis of Variance (ANOVA) was used to compare mean scores on each logit-transformed outcome variable across demographic and phenotype groups. Due to unequal variances across groups, we used Dunnett's T3 post-hoc tests to examine pair-wise comparisons between groups. Group averages were back-transformed for descriptive purposes. In another set of analyses, child demographic and phenotypic characteristics were used in a series of multiple linear regression analyses to predict logit-transformed scores on each outcome variable. The purpose of these analyses was to determine if each demographic and phenotypic characteristic was significantly associated with the outcomes after adjustment for all other variables in the model. For these analyses, indicator variables were created for race, reported by a parent for the child (reference group = other [Black, Asian, Native American]), hair color (reference group = black), eye color (reference = brown), gender (reference = male), and skin color (reference = other). Facial freckling and total body nevus counts were entered as continuous predictors. Only the total number of nevi was included in these analyses, since number of nevi on the face and other body sites resulted in collinearity.

To verify that the study sample was representative of the overall cohort, we first compared the phenotypic characteristics of the 585 children in the study sample with: (1) the 40 children present for skin examinations in 2010 but not included in the sample, and (2) the 520 children in the cohort who were not present for skin examinations in 2010. In order to

determine whether the change in methodology for recording the photographs and computing corresponding scores affected our results, we repeated the ANOVA tests described above for children who completed a skin exam before the change ($n = 231$) and those who completed a skin exam after the change ($n = 354$). We also compared mean scores before and after the change. All statistical tests were two sided and were performed using SPSS for Windows version 16.0 (SPSS, Inc, Chicago, Illinois).

RESULTS

For the purpose of communicating our data in a form that could translate to its use in a clinical setting, observed (untransformed and unadjusted) group means are presented in Table 1. Gender was approximately equally distributed with 52.1% female and 47.9% male. Study participants were mostly non-Hispanic white (79.3%). Although fifty percent of study participants had medium to dark brown hair, children with all hair colors were represented. Green/hazel eye color was most prevalent, followed by brown and blue eye color. Just over 20% of study participants had no observed facial freckles; approximately 40% had either a low or medium-high level of facial freckling. Total body nevus counts ranged from 5 to 205 (median = 48.0). Nevus counts on the face ranged from 0 to 52 (median = 12) and nevus counts on non-facial body sites ranged from 3 to 165 (median = 35).

Table 2 shows demographic and phenotypic characteristics of study participants and associations between participant characteristics and scores on logit-transformed visible, UV, brown and red scores. Race/ethnicity and all phenotypic variables except for number of facial nevus counts were significantly related to scores on each outcome variable. Differences between boys and girls were only statistically significant for red scores, with girls having higher red scores than boys. In general, scores on all outcome variables were highest for children classified as white, non-Hispanic, and as having red hair, blue eyes, medium-high facial freckling, light skin, and a greater number of nevi, overall and on non-facial body sites. Significant group differences were similar across UV, brown and visible scores. Of the three scores, the UV scores varied the most between subgroups, followed by the brown and then the visible scores. There were fewer statistically significant differences in red scores than in UV, brown, or visible scores, and those that did exist tended to be weaker.

Table 3 shows the correlation coefficients between mean visible, UV, brown, and red scores. The highest correlation was for UV and brown scores, and the lowest correlation was for UV and red scores.

Figure 1 shows representative photographs with masks drawn for a child with red (A and B) and a child with blonde-light brown (C and D) hair. Examining each set of photographs reveals that the UV photographs also capture much of the sun damage captured by the visible light photographs. However, there is additional sun damage in the UV photographs not captured by the visible photographs. For the child with red hair (A and B), much though not all of the sun damage in the UV photographs can be accounted for by freckling in the visible photograph. For the child with blonde-light brown hair (B and C), most of the sun damage captured by the UV photograph is not accounted for by freckling in the visible light photograph.

Table 4 shows the results of linear regression analyses predicting logit-transformed scores on each outcome variable. Each demographic and phenotypic variable made an independent contribution to the prediction of UV scores and, as a set, explained 68% of the score variance. Regression results for brown scores were most similar to those for UV scores, followed by visible scores, and red scores. The set of demographic and phenotypic variables

accounted for 47% of the variance in brown scores, with all characteristics other than blonde hair color having independent associations. The regression model explained 41% of the variance in visible scores, with race/ethnicity (non-Hispanic white vs. Other), eye color (green vs. brown), facial freckling, and total mole count showing independent effects. For red scores, the set of demographic and phenotypic variables explained only 8% of the total score variance, and only gender, race/ethnicity, and total body nevus counts were independently associated with scores on that outcome. Facial freckling had the strongest association with UV, brown, and visible scores, accounting for between 16 and 28% of the total variance in those outcome variables.

There were no statistically significant differences in demographic or phenotypic characteristics between the 585 children included in this analysis and either the 40 children who participated in a 2010 skin exam but were not included in this analysis or the 520 children in the cohort who did not participate in skin exams in 2010. Likewise, there were no statistically significant differences between children who participated before ($n = 231$) and after ($n = 354$) the methodological change in capturing UV photos in mean UV scores (.62 vs. .49, respectively, $P = .10$), mean visible (.26 vs. .27 respectively, $P = .27$) scores, mean brown scores (3.22 vs. 3.33, respectively, $P = .59$), or mean red scores (.96 vs. .90, respectively, $P = .34$). Examining each group individually yielded minimal differences in patterns reported in Table 2.

DISCUSSION

We present reference ranges to which dermatologist could compare the UV scores their pediatric patients in Table 1. The severity of sun damage shown in the UV photographs of 12-year-old children correlates closely with phenotypic melanoma risk factors (see Table 2). This study is the first to report this finding in a large population of children, and the results validate the use of UV photography as a measure of sun damage corresponding to known melanoma risk factors. Since photographs showing more apparent sun damage likely have greater impact on behavior,¹⁴ we believe that sun protection interventions incorporating UV photography are likely to have a greater effect on those at higher risk for melanoma.

The results of this study are that freckling, hair color, eye color, base skin color and total body nevus counts predict the severity of sun damage in UV photographs of 12-year-old children. Freckling was the strongest predictor, but the other phenotypic risk factors were also important. Freckling is a pigmentary characteristic that can be seen in visible light and was included in the area of analysis of the photographs. Thus, it is not surprising that freckling predicts the UV scores. However, since the children's eyes were closed for the photographs and their hair was excluded from the area of analysis, hair color and eye color did not directly affect the UV scores. This suggests that the sun damage captured by UV photographs is somewhat different from, and additive to sun damage that can be seen by the naked eye.

That UV photographs capture additional sun damage information is also supported by three of the other findings. First, the correlation between UV and visible scores was low (0.496), suggesting that the photographs employing UV and visible light are measuring different types of damage (see Table 3). Second, the photographs themselves reveal that many spots were detected on the UV photographs that were not detected on the visible light photographs (Figure 1). Third, while nevi on the face did not relate to any of the scores, full body nevi counts did (see Table 4). There may have been too few nevi on the face to significantly affect the scores, but the scores still related to full body nevi counts, a measure more closely related to melanoma risk. The additional sun damage detected by the UV photographs may

represent a form of mottled skin pigmentation not normally visible in standard lighting conditions.

Since the VISIA™ algorithm defines spots by a threshold level of color contrast, the pigmentary structures responsible for producing spots on visible photographs are the same as those that can readily be seen with the naked eye: mostly freckles, though nevi, lentigines, café-au-lait spots and other epidermal structures may also contribute in some individuals. UV radiation penetrates the epidermis and is absorbed and re-emitted by collagen within the dermis.²⁹ Dark spots on UV photographs occur when melanin attenuates UV light entering or exiting the skin. The mottled pigmentation visualized by UV photographs can thus be due to both epidermal and dermal components.^{16,29} Determining whether the pigmentation visualized by UV light but not seen in standard lighting conditions represents epidermal or dermal structures would require biopsies or other noninvasive techniques. We presume the UV photographs are detailing melanin distributions in the epidermis and dermis not readily discernable in visible light. To prove this, histologic correlation with immunostained skin biopsies of photographed skin would be needed. Such work would be unethical in our study population but remains important for confirming that melanin is the chromophore detected by UV photography.

Cross-polarized visible light penetrates deeper into the dermis than UV light and thus the pigmentary lesions responsible for attenuating the brown-component of cross-polarized light may be more related to dermal components, while the lesions responsible for red-component light are more likely to be related to the dispersal of hemoglobin or other vascular abnormalities.¹⁶⁻¹⁸ While vascular abnormalities may also be related to sun damage, the results showed the severity of damage shown on red component-cross polarized images were less related to melanoma risk factors in 12 year-old children. Girls' higher red scores than boy's red scores (0.16 vs. 0.14, Table 2) likely resulted from the girls having more acne at age 12.

It may be that vascular damage becomes more prominent in individuals older than 12 years of age. It is possible that photographs of older individuals, such as college students, would show more sun damage on red-component images. Although neither brown- nor red-component images have been studied in sun protection interventions, the lower cost of the imaging systems available to produce these photographs make them an attractive alternative. For example, while the cost of the VISIA™ system used in our study was approximately \$20,000, Canfield offers a smaller REVEAL™ system that exclusively produces cross-polarized visible photographs for approximately \$5,000. That system is smaller, more portable, and its use of cross-polarized visible rather than UV light may be more acceptable to participants of sun protection interventions.

This study was performed using commercially available software to quantify sun damage shown in ultraviolet, cross-polarized and visible photographs. While the software measures sun damage in an objective and standardized fashion, other algorithms could produce different results. Another limitation of this study is that cosmetic products worn on the face may affect the scores. Pilot study revealed that sunscreen decreased UV scores. While children were asked to wipe their faces for one minute with soap-based wipes, pilot testing showed that this was not sufficient to completely remove the effect of freshly applied sunscreen. However, we found that reported use of sunscreen the day of the UV photograph ($n = 63$) was not related to UV score ($P = .236$; mean for sunscreen group = .52, mean for no-sunscreen group = .68). Since the only statistically significant phenotypic difference between the groups was that were more likely to have green/hazel eyes the overall effect of this bias would likely not impact the link between UV score and phenotypic melanoma risk factors we found. Most (68%) of the skin exams occurred at night from 6 – 8 PM. Since

sunscreen, if applied, was likely applied much earlier in the day, we estimate the magnitude of any potential bias to be small.

UV photography reveals children's severity of sun damage, and shows greater damage in children at high risk for melanoma based on phenotype. Therefore, incorporating UV photographs would likely be an excellent addition to appropriate sun protection counseling and behavioral recommendations. The photographs show patients sun damage that has already been done, and could help dermatologists motivate their high-risk patients to protect themselves from the sun. Current barriers to implementing of this intervention include the cost and time required to record the photographs and scores. It should be noted that these scores were established using VISIA™ software. While this equipment is currently expensive, with increasing popularity of UV photography other less expensive or open-source software algorithms performing similar functions may be developed. Dermatologists can use the results of our study (Table 1) as reference ranges in sun protection interventions. Alternatively, in using UV photography as an intervention, it may not be necessary to provide subjects with their UV score. Rather, this study supports the statement that children whose photographs show more UV damage have a higher risk for melanoma. Simply providing the photograph, which clearly identifies the damage, may be most effective in conveying the message that sunlight causes damage and can increase risk for skin cancer and other undesirable changes in the skin such as wrinkles. In previous intervention studies, photographs were used in this way rather than presenting scores. Simple UV and cross-polarized photographs without corresponding scores can be produced using relatively inexpensive and widely available technology.

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FIGURE 1.

A and **B**, Visible and UV photograph with computerized mask calculating cutaneous pigmentation areas on a child with red hair, respectively. **C** and **D**, Visible and UV photograph for a child with light brown hair, respectively. Note: the color of the lines outlining the mask and pigmentation areas was changed to black and bolded to enhance contrast and optimize viewing.

Table 1

Characteristics of study participants and mean UV, brown, visible and red score with sex, race, hair color, eye color, freckling, base skin color and number of nevi with ranges. These are the observed means and ranges without any transformations.

Characteristic	n (%) [*]	Observed Mean Visible Score [†]			Observed Mean UV Score [†]			Observed Mean Brown Score [†]			Observed Mean Red Score [†]		
		Mean	(SD)		Mean	(SD)		Mean	(SD)		Mean	(SD)	
Overall	585 (100)	1.18	(0.98)		1.48	(2.03)		3.93	(2.56)		0.19	(0.14)	
Sex													
Male	305 (52.1)	1.14	(0.95)		1.40	(2.06)		3.78	(2.48)		0.17	(0.12)	
Female	280 (47.9)	1.22	(1.01)		1.55	(2.00)		4.07	(2.62)		0.20	(0.15)	
Race													
Non-Hispanic white	464 (79.3)	1.25	(1.04)		1.76	(2.15)		4.39	(2.57)		0.19	(0.14)	
Hispanic white	79 (13.5)	0.91	(0.61)		0.51	(0.91)		2.65	(1.48)		0.19	(0.16)	
Black	17 (2.9)	1.36	(1.03)		0.14	(0.49)		1.05	(1.77)		0.13	(0.12)	
Asian	24 (4.1)	0.62	(0.27)		0.06	(0.07)		1.46	(0.63)		0.11	(0.09)	
Native American	1 (0.2)	---	---		---	---		---	---		---	---	
Hair color													
Red	21 (3.6)	2.43	(1.73)		4.80	(2.85)		7.48	(3.60)		0.26	(0.18)	
Blonde	40 (6.9)	0.94	(0.70)		1.56	(1.66)		3.96	(1.88)		0.17	(0.12)	
Blondish brown-light brown	145 (24.9)	1.19	(0.92)		1.68	(2.00)		4.28	(2.31)		0.20	(0.14)	
Medium-dark brown	292 (50.1)	1.19	(1.00)		1.49	(2.01)		4.05	(2.54)		0.18	(0.13)	
Black	85 (14.6)	0.93	(0.65)		0.26	(0.44)		2.04	(1.47)		0.18	(0.16)	
Eye color													
Blue	141 (24.2)	1.28	(1.00)		2.20	(2.30)		4.88	(2.48)		0.21	(0.16)	
Green/hazel	229 (39.3)	1.30	(1.08)		1.78	(2.19)		4.40	(2.66)		0.19	(0.12)	
Brown	213 (36.5)	0.99	(0.83)		0.68	(1.25)		2.80	(2.05)		0.17	(0.14)	
Facial freckling													
Med-high (40-100)	221 (37.8)	1.79	(1.24)		2.95	(2.52)		6.18	(2.60)		0.21	(0.14)	
Low (10-30)	233 (39.8)	0.83	(0.50)		0.75	(0.88)		2.97	(1.15)		0.18	(0.13)	
None (0)	131 (22.4)	0.78	(0.55)		0.27	(0.54)		1.85	(1.00)		0.16	(0.14)	
Base Skin Color (L scale)													
Light (60)	221 (37.8)	1.39	(1.21)		2.46	(2.52)		5.03	(2.84)		0.21	(0.14)	

Characteristic	n (%) [*]	Observed Mean Visible Score [†]		Observed Mean UV Score [†]		Observed Mean Brown Score [†]		Observed Mean Red Score [†]	
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Other (< 60)	363 (62.1)	1.06 (0.80)	0.88 (1.35)			3.27 (2.11)		0.18 (0.14)	
Total body Nevus count									
63+	197 (33.7)	1.40 (1.01)	2.03 (2.08)			4.92 (2.60)		0.21 (0.14)	
37-62	190 (32.5)	1.06 (0.73)	1.20 (1.66)			3.72 (2.09)		0.18 (0.12)	
5-36	198 (33.8)	1.08 (1.13)	1.19 (2.18)			3.16 (2.62)		0.18 (0.15)	
Number of nevi on the face									
15+	203 (34.7)	1.06 (0.75)	1.11 (1.48)			3.71 (1.98)		0.19 (0.13)	
9-14	172 (29.4)	1.09 (0.85)	1.32 (1.73)			3.82 (2.29)		0.18 (0.13)	
0-8	210 (35.9)	1.37 (1.23)	1.96 (2.56)			4.24 (3.17)		0.19 (0.16)	
Number of nevi on non-facial body sites									
48+	197 (33.7)	1.46 (1.03)	2.20 (2.09)			5.16 (2.57)		0.21 (0.14)	
26-47	194 (33.2)	1.02 (0.69)	1.17 (1.66)			3.64 (2.02)		0.18 (0.13)	
3-25	194 (33.2)	1.06 (1.06)	1.04 (2.11)			2.98 (2.54)		0.17 (0.15)	

* Percentages are calculated exclusive of children with an "other" designation or missing data and, due to rounding, may not total 100.

Table 2

Characteristics of study participants and analysis of relationship of mean UV, brown, visible and red score with sex, race, hair color, eye color, freckling, base skin color and number of nevi. The mean scores represent back-transformed means after applying a logit transformation.

Characteristic	n (%) [*]	Mean Visible Score [†]		Mean UV Score [†]		Mean Brown Score [†]		Mean Red Score [†]	
		Mean (95%CI)		Mean (95% CI)		Mean (95% CI)		Mean (95%CI)	
Overall	585 (100)	0.92 (0.87-0.97)		0.51 (0.44-0.59)		3.06 (2.84-3.31)		0.15 (0.14-0.16)	
Sex									
Male	305 (52.1)	0.89 (0.82-0.97)		0.46 (0.37-0.58)		2.85 (2.51-3.25)		0.14 (0.13-0.15) ^{//}	
Female	280 (47.9)	0.94 (0.87-1.02)		0.56 (0.48-0.68)		3.27 (2.99-3.57)		0.16 (0.15-0.17)	
Race									
Non-Hispanic white	464 (79.3)	0.97 (0.91-1.03) ^{a, ‡}		0.86 (0.76-0.97) ^{a, ‡}		3.77 (3.58-3.98) ^{a, ‡}		0.16 (0.15-0.17) ^{a, ‡}	
Hispanic white	79 (13.5)	0.77 (0.67-0.87) ^b		0.14 (0.09-0.22) ^b		2.08 (1.63-2.64) ^b		0.15 (0.13-0.17) ^a	
Black	17 (2.9)	1.04 (0.69-1.55) ^{a,b}		0.02 (0.00-0.03) ^c		0.28 (0.06-0.80) ^c		0.09 (0.05-0.15) ^{a,b}	
Asian	24 (4.1)	0.57 (0.47-0.68) ^c		0.03 (0.01-0.05) ^c		1.28 (0.98-1.65) ^c		0.09 (0.07-0.12) ^b	
Native American	1 (0.2)	-- --		---		---		---	
Hair color									
Red	21 (3.6)	1.94 (1.41-2.68) ^{a, ‡}		3.76 (2.53-5.57) ^{a, ‡}		6.72 (5.32-8.46) ^{a, ‡}		0.22 (0.17-0.28) ^{a, §}	
Blonde	40 (6.9)	0.77 (0.63-0.94) ^b		0.97 (0.70-1.36) ^b		3.62 (3.16-4.15) ^b		0.14 (0.12-0.17) ^{a,b}	
Blondish brown- light brown	145 (24.9)	0.97 (0.87-1.08) ^b		0.96 (0.80-1.16) ^b		3.77 (3.46-4.11) ^b		0.16 (0.15-0.18) ^{a,b}	
Medium-dark brown	292 (50.1)	0.91 (0.84-0.99) ^b		0.56 (0.47-0.68) ^c		3.32 (3.03-3.63) ^b		0.15 (0.13-0.16) ^{a,b}	
Black	85 (14.6)	0.77 (0.67-0.88) ^b		0.05 (0.03-0.09) ^d		1.22 (0.87-1.71) ^c		0.12 (0.10-0.15) ^b	
Eye color									
Blue	141 (24.2)	1.02 (0.92-1.14) ^{a, ‡}		1.31 (1.09-1.58) ^{a, ‡}		4.37 (4.03-4.74) ^{a, ‡}		0.16 (0.14-0.18) ^{a, //}	
Green/hazel	229 (39.3)	1.00 (0.91-1.10) ^a		0.86 (0.72-1.03) ^b		3.78 (3.51-4.07) ^b		0.16 (0.14-0.17) ^a	
Brown	213 (36.5)	0.78 (0.71-0.85) ^b		0.15 (0.12-0.21) ^c		1.92 (1.61-2.28) ^c		0.13 (0.12-0.15) ^b	
Facial freckling									
Med-high (40-100)	221 (37.8)	1.47 (1.36-1.60) ^{a, ‡}		1.99 (1.74-2.27) ^{a, ‡}		5.70 (5.38-6.03) ^{a, ‡}		0.17 (0.16-0.19) ^{a, ‡}	
Low (10-30)	233 (39.8)	0.71 (0.67-0.77) ^b		0.38 (0.32-0.45) ^b		2.75 (2.59-2.90) ^b		0.14 (0.13-0.16) ^b	
None (0)	131 (22.4)	0.64 (0.58-0.71) ^b		0.08 (0.06-0.12) ^c		1.28 (1.00-1.63) ^c		0.12 (0.11-0.14) ^b	
Base Skin Color (L scale)									

Characteristic	n (%) [*]	Mean Visible Score [†]		Mean UV Score [†]		Mean Brown Score [†]		Mean Red Score [†]	
		Mean	(95%CI)	Mean	(95% CI)	Mean	(95% CI)	Mean	(95%CI)
Light (< 60)	221 (37.8)	1.05	(0.95-1.16) [‡]	1.38	(1.17-1.62) [‡]	4.37	(4.06-4.70) [‡]	0.17	(0.15-0.18) [§]
Other (< 60)	363 (62.2)	0.85	(0.79-0.91)	0.28	(0.23-0.34)	2.47	(2.21-2.75)	0.14	(0.13-0.15)
Total body nevus count									
63+	197 (33.7)	1.11	(1.01-1.22) ^{a, ‡}	1.19	(1.02-1.41) ^{a, ‡}	4.34	(4.04-4.67) ^{a, ‡}	0.17	(0.15-0.18) ^{a, §}
37-62	190 (32.5)	0.89	(0.82-0.96) ^b	0.51	(0.41-0.62) ^b	3.21	(2.95-3.49) ^b	0.15	(0.14-0.16) ^{a,b}
5-36	198 (33.8)	0.79	(0.71-0.87) ^b	0.22	(0.16-0.30) ^c	2.06	(1.71-2.49) ^c	0.13	(0.12-0.15) ^b
Number of nevi on the face									
15+	203 (34.7)	0.87	(0.80-0.95)	0.53	(0.44-0.64)	3.30	(3.08-3.53)	0.15	(0.14-0.17)
9-14	172 (29.4)	0.88	(0.80-0.97)	0.54	(0.43-0.69)	3.20	(2.89-3.54)	0.14	(0.13-0.16)
0-8	210 (35.9)	1.00	(0.90-1.11)	0.46	(0.33-0.64)	2.75	(2.28-3.32)	0.15	(0.13-0.16)
Number of nevi on non-facial body sites									
48+	197 (33.7)	1.17	(1.06-1.29) ^{a, ‡}	1.36	(1.16-1.59) ^{a, ‡}	4.60	(4.29-4.94) ^{a, ‡}	0.17	(0.16-0.19) ^{a, ‡}
26-47	194 (33.2)	0.86	(0.79-0.93) ^b	0.52	(0.43-0.63) ^b	3.19	(2.96-3.43) ^b	0.15	(0.14-0.17) ^{a,b}
3-25	194 (33.2)	0.77	(0.69-0.85) ^b	0.22	(0.13-0.26) ^c	1.94	(1.60-2.35) ^c	0.13	(0.11-0.14) ^b

^{*} Percentages are calculated exclusive of children with an "other" designation or missing data and, due to rounding, may not total 100.

[†] Superscript letters "a," "b," "c," and "d" denote statistically significant differences based on Dunnett's T3 post-hoc pairwise comparison tests between groups.

[‡] $P < .001$

[§] $P < .01$

$\parallel P < .05$

Table 3

Correlation between mean UV, brown, visible and red scores. All means are significantly correlated to $P < .001$.

	Brown	Visible	Red
UV	0.830	0.496	0.350
Brown	1	0.410	0.368
Visible	--	1	0.517

Table 4

Results of multiple linear regression predicting logit transformed mean UV, brown, visible and red scores. Regression coefficients are based on transformed scores and represent the change in the logit of the percent score on each outcome variable for a one-unit increase in each predictor variable.

Predictor	Mean Visible Score				Mean UV Score			
	Beta	B (95% CI)	P	sr ²	Beta	B (95% CI)	P	sr ²
Gender								
Female	0.05	0.08 (-0.01-0.17)	.10	0.003	0.09	0.29 (0.14-0.44)	<.001	0.007
Male	ref	--	--	--	ref	--	--	--
Race/Ethnicity								
Non-Hispanic white	-0.12	-0.20 (-0.41-0.00)	.05	0.004	0.40	1.82 (1.43-2.20)	<.001	0.043
Hispanic white	-0.06	-0.12 (-0.32-0.09)	.27	0.001	0.26	1.42 (1.04-1.81)	<.001	0.026
Other	ref	--	--	--	ref	--	--	--
Hair Color								
Red	0.07	0.25 (-0.04-0.54)	.09	0.003	0.14	1.40 (0.86-1.93)	<.001	0.013
Blonde	-0.11	-0.17 (-0.35-0.01)	.06	0.004	0.18	0.71 (0.38-1.04)	<.001	0.009
Blondish brown- Medium-dark brown	-0.10	-0.13 (-0.29-0.02)	.09	0.003	0.16	0.58 (0.30-0.87)	<.001	0.008
Black	ref	--	--	--	ref	--	--	--
Eye Color								
Blue	0.04	0.07 (-0.08-0.21)	.37	0.001	0.13	0.56 (0.30-0.83)	<.001	0.009
Green	0.10	0.14 (0.02-0.26)	.02	0.005	0.13	0.51 (0.29-0.73)	<.001	0.010
Brown	ref	--	--	--	ref	--	--	--
Facial Freckling (0-100)	0.59	0.02 (0.02-0.02)	<.001	0.282	0.44	0.03 (0.03-0.04)	<.001	0.162
Base Skin Color (L scale)								
Light (< 60)	0.01	0.01 (-0.09-0.11)	.81	0.000	0.17	0.65 (0.47-0.83)	<.001	0.024
Other (< 60)	ref	--	--	--	ref	--	--	--
Total Body Nevus Count	0.14	0.00 (0.00-0.01)	<.001	0.017	0.14	0.01 (0.01-0.01)	<.001	0.016
Predictor	Mean Brown Score				Mean Red Score			
	Beta	B (95% CI)	P	sr ²	Beta	B (95% CI)	P	sr ²
Gender								
Female	0.10	0.20 (0.10-0.31)	<.001	0.010	0.13	0.19 (0.07-0.30)	.002	0.016

Predictor	Mean Visible Score					Mean UV Score				
	Beta	B (95% CI)	P	sr ²	Beta	B (95% CI)	P	sr ²		
Male	ref	-- --	--	--	ref	-- --	--	--	--	--
Race/Ethnicity										
Non-Hispanic white	0.41	0.98 (0.73-1.23)	<.001	0.047	0.17	0.30 (0.04-0.56)	.026	0.008		
Hispanic white	0.34	0.96 (0.71-1.21)	<.001	0.044	0.20	0.42 (0.15-0.68)	.002	0.015		
Other	ref	-- --	--	--	ref	-- --	--	--	--	--
Hair Color										
Red	0.09	0.45 (0.11-0.81)	.010	0.005	0.07	0.26 (-0.11-0.62)	.170	0.003		
Blonde	0.09	0.19 (-0.02-0.41)	.077	0.003	-0.01	-0.02 (-0.25-0.21)	.857	0.000		
Blondish brown- Medium-dark brown	0.12	0.24 (0.05-0.43)	.013	0.005	-0.04	-0.06 (-0.26-0.13)	.525	0.001		
Black	ref	-- --	--	--	ref	-- --	--	--	--	--
Eye Color										
Blue	0.08	0.18 (0.01-0.35)	.040	0.003	0.02	0.04 (-0.14-0.22)	.689	0.000		
Green	0.09	0.18 (0.03-0.32)	.017	0.004	0.02	0.03 (-0.12-0.18)	.701	0.000		
Brown	ref	-- --	--	--	ref	-- --	--	--	--	--
Facial Freckling (0-100)	0.46	0.02 (0.02-0.02)	<.001	0.167	0.11	0.00 (0.00-0.01)	.010	0.010		
Base Skin Color (L scale)										
Light (< 60)	0.08	0.16 (0.04-0.28)	.010	0.005	0.07	0.11 (-0.02-0.23)	.097	0.004		
Other (> 60)	ref	-- --	--	--	ref	-- --	--	--	--	--
Total Body Nevus Count	0.13	0.00 (0.00-0.01)	<.001	0.015	0.14	0.00 (0.00-0.01)	.001	0.017		

sr² is the squared semi-partial correlation representing the amount by which R² will decrease if the variable is removed from the regression equation. These results are for Colorado children born in 1998 (n = 585). Adjusted R² visible = .41, adjusted R² UV = .68, adjusted R² brown = .47, adjusted R² red = .08.