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UV Responses in Native Hawaiians or Other Pacific Islanders and Asians Residing in Hawai'i and in Maryland

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Abstract

Background—UV exposure causes a wide range of skin damage including cutaneous melanoma. The mechanisms of cellular and molecular damage as well as erythematous and pigmentation responses to UV exposure have largely been studied in the White population.

Methods—This study systematically investigates responses to UV exposure in the Native Hawaiian and Pacific Islanders (NHPI) and Asian populations living in Hawai'i (A/HI) as well as in Asians living in Maryland (A/MD).

Results—Our analyses indicate that the NHPI population is less sensitive to UV exposure than the A/HI population. Comparisons between the two Asian groups suggest that, despite slightly but not statistically different baseline constitutive pigmentation (pre-UV exposure), the A/HI and A/MD had similar UV sensitivity, measured as minimal erythematous dose (MED). However, the A/MD population had higher levels of oxy-hemoglobin at doses of 2.0, 2.8 and 4.0 MED. Unexpectedly the A/MD subjects retained higher levels of pigmentation 2 weeks post UV exposure.

Conclusion—This study provides insight into UV responses of the inhabitants of Hawai'i and shows that such responses are statistically significant for relatively small samples of Native Hawaiian and Pacific Islanders, and for Asians living in Hawai'i and Asians living in Maryland.

Keywords

ultraviolet radiation; race/ethnicity; erythema; pigmentation

Introduction

Hawai'i's insolation, the intensity of solar radiation received at the earth's surface, is higher than at any other location in the U.S. The amount of environmental ultraviolet radiation

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(UV) in Hawai'i in terms of the UV Index (1, 2) varies from 6–7 in winter to 11–12 in summer (3). Yet, no studies have been conducted on cutaneous responses to UV of Hawai'i residents or Native Hawaiians.

Current U.S. classification recognizes 5 main racial and ethnicity (R/E) categories: American Indian or Alaska Native, Asian (A), Black or African American, Native Hawaiian or Other Pacific Islander (NHPI), and White. According to this classification (2010 US Census), the largest R/E groups in Hawai'i are Asians (38.6%) followed by Whites (24.7%) and Native Hawaiian or other Pacific Islanders (NHPI, 10.0%). A relatively large (23.6%) proportion of Hawai'i inhabitants reports belonging to two or more racial groups. Nationwide this value is 2.9%. Hence, by the R/E criteria, Hawai'i is quite heterogeneous and a prime location for exploration of any bioeffects related to NHPI.

It is important to note that associations between R/E, skin color, pigmentation, and UV response may seem obvious, but detailed studies on the human genome indicate that no genetically distinguishable subspecies can be ascribed to human races or ethnicities. There is more genetic variation within races than exists between them (4). Nevertheless, many scientific reports note R/E in the description of study cohorts or even compare responses of different R/E groups (5–8). For example, the U.S. skin cancer incidence and mortality rates are provided for individual R/E groups and geographic locations (9). According to the Center for Disease Control and Prevention (10), in 2008, the incidence rates for melanoma of the skin, per 100,000 persons living in the US, were 21.1 for Whites, 3.8 for American Indians or Alaska Natives, 4.2 for Hispanics, 1.3 for combined Asians and NHPI and 1.0 for Black or African Americans. New cases of melanoma diagnosed in Hawai'i residents have increased steadily over the past thirty-three years, at a higher rate than other cancers. Among Asians and NHPI in the US, the melanoma incidence increased by nearly 54% from 1.1 in 1992 to 1.7 in 2009 (12).

Within the last decade, extensive studies of UV bioeffects in the skin were conducted jointly by the Food and Drug Administration (FDA) and the National Cancer Institute (NCI). These studies explored cellular and molecular damage in UV-exposed human skin (8), mechanisms of erythema and pigmentation response (13, 14), explored relationships between skin color, DNA damage, and UV sensitivity (15, 16), and the effects of repeated UV exposures (17, 18).

The FDA/NCI studies were conducted in the state of Maryland, and Asians, Black or African Americans, and Whites were well represented among 103 volunteer subjects. However, only 2 NHPI volunteered for the study cohort. To fill in this gap, we developed a protocol for a study to be conducted in Hawai'i. We concentrated on erythema responses since they are widely used in safety and performance standards (19 – 21) and in testing of UV-related products (22). We also evaluated changes in skin pigmentation. These responses can be assessed visually or instrumentally.

In this paper, we provide basic parameters of UV responses in NHPI and compare UV sensitivity between NHPI and Asians. Further, we compare UV responses in Asians residing in Hawai'i (A/HI) with those living in Maryland (A/MD). These data demonstrate that by

using identical protocols, including the same UV sources (i.e. emission spectra) and dosimetry, it is possible to directly compare studies on UV bioeffects conducted at different research sites.

Materials and Methods

Subjects

The Hawai'i part of the study was conducted according to protocol CHS No. 12158, FWA 3526, IRB registration #027, approved by the University of Hawai'i Committee on Human Studies. The Maryland part of the study was conducted according to protocol #99-002-R approved by the Research Involving Human Subjects Committee of the U.S. Food and Drug Administration. The two protocols were identical except that different model photographic cameras and different spectrophotometers were used, as described below. All volunteer subjects were at least 18 years of age, gave prior informed consent and were examined by a dermatologist. Detailed inclusion and exclusion criteria can be found in Tadokoro *et al.* (8). The subject's race and ethnicity were self-reported.

The 26-subject Hawai'i cohort was recruited in Oahu, Hawai'i, from advertisements. It consisted of 12 NHPI (Native Hawaiians, Maoris, and Samoans) and 14 Asians (Chinese, Filipinos, Japanese, Korean, and Okinawans). Enrollment of the 12 Maryland Asian (Chinese, Filipinos and Japanese) subjects (a part of a larger cohort) was described in Tadokoro *et al.* (8).

The skin phototype of each subject volunteer was determined according to Fitzpatrick (23). Half-values (i.e., 3.5, 4.5) were assigned when the responses placed the subject between phototypes. Details were reported in Tadokoro *et al.* (8) and Miller *et al.* (17).

UV source and dosimetry

Identical UV sources were used at both the Maryland and the Hawai'i study sites. They consisted of an assembly of eight FS lamps (FSX24T12/UVB/HO, National Biological Corp., Twinsburg, OH) equipped with a Kodacel filter (Eastman Chemical Products, Kingsport, TN) to remove the UVC component. The resulting spectrum consisted of approximately 60% UVA and 40% UVB radiation. The emission spectra of the sources are shown in Figure 1. The emission spectra were measured at 2-nm intervals with an Optronic Laboratories (Orlando, Florida) Model 754 portable spectroradiometer. This system employs a photomultiplier tube detector and a double-grating monochromator to minimize stray light. The input optics consisted of a Spectralon-coated integrating sphere.

UV doses used in the experiments were wavelength-weighted at 297 nm using the Commission Internationale de l'Eclairage (CIE) reference action spectrum for erythema (23) and expressed in SED (standard erythema dose). One SED is equivalent to 100 J/m²-eff (24).

Seven 2 × 2 cm dorsal skin areas were irradiated with increasing doses expected to yield 0.5, 0.7, 1.0, 1.4, 2.0, 2.8, and 4.0 MED. The use distance (22–25 cm) was chosen to deliver approximately 1 SED per minute. Prior to each exposure, a low-profile detector (SSD 001A;

International Light, Newburyport, MA) coupled to a radiometer (IL1700 in Maryland, IL1400A in Hawai'i; International Light) was used to measure the intensity in each spot on the volunteer's back and to calculate the required exposure time. This low-profile detector was calibrated using measurements taken with the spectroradiometer.

MED and MMD determination

The minimal erythral dose (MED) was determined 24 hours after exposure. The UV exposed areas were examined visually under illumination from general purpose fluorescent lamps. The response was evaluated by trained observers using a grading scale from 0 (no reaction) to 5 (violaceous red) as described in Tadokoro *et al.* (8). The MED was the smallest UV dose that caused a pink erythema (grade 2) with at least one distinct border.

The minimal melanogenic dose (MMD) was determined 8 days after exposure using the same sites as those used for MED determination. A grading scale of 0 (no reaction) to 4 (dark brown) was used (8). The smallest dose that produced a light brown tan with at least one border was given a grade of 2. The dose responsible for this effect was defined as the MMD.

Photographic documentation

At every scheduled visit (Day 0, before exposure, and Days 1, 2, 8 and 16 after exposure), each volunteer's back was photographed (see Figure 2) to document the appearance of the skin at different stages of the study as described in Tadokoro *et al.* (8). The Hawai'i study used a single-lens reflex digital camera, Nikon D-100 with 28–105 mm lens; this camera contains a 23.7×15.6 mm, 12-bit RGB CCD with 6.31 million pixels. The Maryland study used a single-lens reflex digital camera Nikon D-1 with 28 mm lens; this camera contains a 23.7×16.7 mm CCD which outputs 2.62 million pixels (Nikon Corporation, Tokyo, Japan).

Diffuse reflectance spectrometry (DRS)

Similar instruments, the Minolta CM-2600 (Konica Minolta Sensing Inc., Osaka, Japan) and Minolta CM-2002 (Minolta Corp, Ramsey NJ, USA) were used in Hawai'i and Maryland, respectively. These two instruments are expected to produce equivalent results. Skin reflectance was measured from 400 to 700 nm at 10 nm intervals. These measurements were taken at each visit, i.e., on Day 0 (before irradiation) and on Days 1, 2, 8 and 16. They were taken on the seven study areas and adjacent unexposed control areas, in triplicate, and averaged. These data were used to derive the lightness, L^* (a measure of skin color, as perceived by the human eye), as defined in the CIE tristimulus scheme (L^* of white color = 100, L^* of total black = 0) (25). They were also used to determine the apparent concentration of oxyhemoglobin (oxy-Hb) levels and melanin in the skin (hereafter referred to as 'melanin content') according to Stamatas *et al.* (26).

Statistical analysis

All statistical analyses were conducted in SAS v9.2 (SAS Institute, Cary, N.C.); p-values and/or adjusted p-values 0.05 were considered as indicating statistical significance. Differences in skin characteristics among the three R/E groups were analyzed with an analysis of variance model. A Bonferroni correction (27) was used in the presence of a

significant R/E group effect to compare the NHPI and A/HI groups, and the A/HI and the A/MD groups.

A growth curve model, which took into account the unequal dose intervals in the seven-exposure series, was used to assess the effect of R/E and increasing MED dose on oxy-Hb and melanin. P-values for multiple comparisons were adjusted with Bonferroni methods (27).

Results

Subjects were divided into three groups based on self-reporting: Native Hawaiians or other Pacific Islanders, living in Hawai'i (NHPI, 12 subjects), Asians living in Hawai'i (A/HI, 14 subjects), and Asians living in Maryland (A/MD, 12 subjects) (Table 1). The two Hawai'i study groups (NHPI and A/HI) had similar mean age and gender distributions: 28.0 yrs, SD 9.5, 67% male (NHPI) and 29.9 yrs, SD 11.6, 64% male (A/HI). The mean age in the A/MD cohort was much higher (50.3 years, SD 13.1) than in the two Hawai'i groups. Also, the proportion of males was lower (33%) in the A/MD group.

Phototype, constitutive skin color and melanin

The median phototype of NHPI skin (4.5, range 1.0) was significantly higher than that of the Asian groups (Kruskal Wallis p-value 0.0002). The median phototypes of A/HI and A/MD groups were the same (3.25, range 1.5).

The raw mean L* for the NHPI group was 3.8 points lower than the raw mean L* for the A/HI skin, which approached statistical significance with a p-value of 0.0551. The raw mean L* for the A/HI group was 5.8 points lower than the raw mean L* for the A/MD group (p-value 0.0901), indicating that the color of their unexposed skin was darker.

The measurements of melanin content showed similar trends. The mean melanin content for the NHPI group was the highest, though not significantly different than the mean melanin content for the A/HI group (p-value 0.1982); the mean melanin content for the A/MD group was the lowest, though not significantly different than that of the A/HI group (p-value 0.1608).

Erythema and pigmentation responses

Figure 2 shows examples of the visible post-UV-exposure changes in NHPI, A/HI and A/MD skin. The easily discernible 24-h erythema intensified on day 2. UV-induced pigmentation seen 8 days after exposure had partially faded by day 16. Similar patterns were seen in all 3 study groups. These visible changes were used to determine the MED and MMD values (Table 2). The mean MED of NHPI skin, at 5.47 SED (SD 1.67) was higher than that of the A/HI skin (4.10 SED, SD 1.68), which approached statistical significance with a p-value of 0.0598. The mean MED of A/HI skin was very similar to that of the A/MD skin (4.08 SED, SD 0.85, p-value 0.9988).

The mean MMD of NHPI skin was 7.02 SED (SD 2.54), significantly greater than the mean of A/HI skin (p-value 0.0128), while the mean MMD of A/HI and A/MD skin were very similar: 4.82 SED (SD 1.36) and 5.07 SED (SD 1.42), respectively (p-value 0.9348).

Correlations between MED and MMD

There were strong correlations between the MED and MMD of unexposed skin within each R/E group (Figure 3). The highest correlation was seen within the A/HI group ($r=0.92$) and the lowest within the A/MD group ($r=0.85$). There is no statistically significant evidence that the strength of the correlation between MED and MMD differs among the three R/E groups. The MMD/MED ratio of the NHPI group was 1.3, similar to that of A/HI and A/MD (1.2).

Dynamics of erythema and pigmentation response

DRS makes it possible to measure UV-induced changes in cutaneous oxy-Hb and melanin, even in the presence of considerable pigmentation (26). We used these non-invasive markers to compare UV responses in the three R/E groups.

The mean oxy-Hb level of unexposed A/MD skin is 0.31 lower than the mean oxy-Hb level of the NHPI (p-value 0.0018) and 0.17 lower than the mean oxy-Hb of the A/HI (p-value 0.0830) group. We observed some significant differences in the change in oxy-Hb levels (after UV exposure) among the R/E groups (Figure 4). On Day 2 post exposure, A/HI group had a significantly greater change from baseline than the NHPI group at both 2 MED (1.3 vs 1.0, p-value 0.0308) and 2.8 MED (1.7 vs 1.4, p-value 0.0540). Significant differences in the change in oxy-Hb were observed between the two Asian groups on Days 8 and 16 at higher MED doses. On Day 8, the mean change in oxy-Hb was significantly greater in the A/MD group than the A/HI group at both 2.8 MED (0.7 vs. 0.4, p-value 0.0052) and 4 MED (0.9 vs 0.4 p-value 0.0012). On Day 16, at 4 MED, the change in oxy-Hb remained significantly higher in the A/MD group (0.5) than in the A/HI group (0.3, p-value 0.0034).

Post-exposure changes in melanin levels are shown in Figure 5. On Days 1 and 2, no significant change in melanin levels was observed across the R/E groups as is to be expected since the melanogenic system takes 3–5 days to begin producing de novo pigmentation. On Days 8 and 16, however, the increase in melanin content was UV dose-dependent in all three R/E groups ($p<0.0001$) and appears to saturate for all groups above the dose of 2.8 MED. On day 8, all three groups had similar changes in melanin content at all dose levels. At day 16 the A/MD group has retained the largest amount of melanin compared to either group in Hawai'i even though it had the lowest constitutive pigmentation levels. Also, at day 16, the A/HI group retained an intermediary level of melanin, while the NHPI group had almost returned to baseline.

Discussion

Use of identical protocol in two different research sites

To our knowledge, this is the first systematic study evaluating sensitivity of inhabitants of Hawai'i to ultraviolet radiation. We investigated UV responses in NHPI and A/HI groups that comprise 48.6% of the population in Hawai'i. In addition, we compared these groups

with Asians residing in Maryland (A/MD). This protocol gave us not only insight into photobiological responses of Hawaiians but also made it possible to evaluate the logistics of the use of analogous protocols at two remote locations with different UV index annual averages (9.5 for Honolulu, HI and 4.8 for Baltimore, MD in 2011) (28).

We used identical procedures in each location (except for the acquisition of biopsies only in Maryland). However, there were some unavoidable differences. First, the trained observers responsible for the visual observations of erythema and pigmentation were not the same individuals although the scales used were identical. Second, the UV sources used for irradiation were the same model and incorporated the same filtration, but there may have been differences in the aging behavior of the lamps and/or filters that could have produced slight differences in spectral output over the course of the study. Unfortunately, the precise instrumentation required for measuring spectral irradiance was only available at the MD location, which meant that the characterization of the UV source was performed at the beginning and end of the study on the UV source used in the Hawai'i study. In the interim, a handheld detector was used to measure the UV intensity at the exposure position on the subjects' backs. This detector had previously been calibrated with the spectral irradiance measurements, but it could only detect changes in intensity, not spectral changes. In summary, using the same protocol at two different locations/facilities is feasible, but must be undertaken with careful preparation and execution, especially where dosimetry is concerned.

Using an identical protocol in two different geographic locations provided us the capability to expand our pool of Asians and Pacific Islanders, which is a useful technique when available volunteers in a particular sub-group may be limited. The results from the study conducted in Hawai'i showed that the UV sensitivity (evaluated by MED) of NHPI and A/HI subjects fell in between the range of 1.50 and 19.90 SED found in the MD study of all 5 R/E categories (15). A majority of the volunteers in the combined pool had skin type III (16 subjects) and skin type IV (18 subjects). Their average MED's were 3.94 SED (SD 1.44) and 5.15 SED (SD 1.57), respectively, similar to those reported in Harrison and Young (29).

Correlations between MED and MMD

Published reports show that a variety of correlations may exist between the MED and MMD, i.e., MMD may be lower, equal, or higher than MED. We found that NHPI subjects have significantly higher mean MMD than the A/HI group while they have more constitutive pigmentation (as measured by L^*). The study of Ravnbak et al. (30) reports MMD higher in darker-skinned Indian/Pakistani volunteers than in fair-skinned Scandinavians volunteers. Previously, Pathak and Fanselow (31) found that MMD was the same as MED in skin type II subjects, but that in skin types III and IV, frequently MMD was lower than MED. Previous clinical studies (15) showed 68% of the multi-R/E subjects having $MMD > MED$. An overwhelming majority of Black or African American subjects had $MMD/MED \geq 1$ while the majority of White subjects had a $MMD/MED \leq 2$ (which is contrary to Pathak and Fanselow (31)). This is most likely due to the fact that Pathak and Fanselow used solar light, while Tadokoro et al. (8) and Beer et al. (15) used a more-UVB rich UV source. Although there is a proportion of subjects from each group (see Figure 3) that have $MMD/MED = 1$, the majority of subjects fall between MMD/MED of 1 and 2. Kawada (32) found the MMD

greater than the corresponding MED in all skin types of 65 Japanese volunteers. Rawlings et al. (33) noted that studies on Japanese subjects found that both MED and MMD increased with increasing skin type and that this is completely different than what is observed in Caucasians. It is quite possible that the differences found in the literature are a result of the different spectra of the UV source (30) and/or different UV response in the different R/E groups.

Differences in response to UV exposure between groups

The mean MED of NHPI was significantly higher than that of both Asian groups. In addition, no significant differences were observed in the oxy-Hb or melanin levels after 1 MED UV exposure between the NHPI and the A/HI groups, despite the fact that, on average, the NHPI were given a 35% higher UV dose than either Asian group. The increase in oxy-Hb is a measure of erythema intensity (34); hence, this implies that the NHPI skin is more resistant to sunburn, most likely due to the slightly higher melanin content.

Significant differences in oxy-Hb were observed between the A/HI and the A/MD groups at the higher UVR exposures on Day 8 (at 2.8 and 4 MED) and Day 16 (at 4 MED), indicating a more persistent UVR erythema in the A/MD than in the A/HI group. Prolonged erythema had been associated with non-melanoma skin cancer (35) and cutaneous carcinoma (36). Wilson *et al.* (35) reported that 4 weeks after a 5 MED UVR exposure, erythema remained present in all skin type I subjects but had disappeared in 15 out of 16 skin type IV subjects. In their study, Jung *et al.* (37) showed that even if the MED or skin type of the study groups are not significantly different, erythema persistence following a UVR exposure of 8 MED can vary. A prolonged erythema was observed in 80% of the skin carcinoma group but only 28% in the control group that was monitored over 3 weeks.

UV responses of Asians living in HI and MD

As expected, higher environmental UV in Hawai'i resulted in darker skin color (L^*), and higher melanin content in the A/HI group than in the A/MD group (Table 2), though this was not statistically significant. However, there was not an added advantage in terms of having a higher sunburn resistance (based on MED values) for Asians living in Hawai'i compared to those in Maryland. Also, the MMD of A/HI was roughly the same as the A/MD suggesting there was no improved melanocompetency. Unexpectedly, the A/MD retained higher levels of melanin 2 weeks after UV exposure which is contrary to expectations considering the A/HI had higher constitutive pigmentation levels. One might expect more efficient melanin production and better maintenance of pigmentation in the A/HI considering equivalent UV sensitivity, but different environmental UV backgrounds. However, the greater persistence of pigmentation in the A/MD group might indicate slower repair of the DNA damage that produced the pigmentation, possibly due to less photo-adaptation from living in an area of lower ambient UV.

Conclusions

This photobiological study for the first time quantifies information of UV responses (erythema and melanogenesis) in Native Hawaiians and compares responses of Asians living

in two different UV environments. The NHPI group had a significantly higher resistance to sunburn, probably due to their higher constitutive skin color. Despite living in drastically different UV environments, the A/HI and A/MD had similar UV sensitivity and melanocompetency as measured by their MED and MMD. However, we did see a difference in the return to baseline skin color among these groups. The A/MD group had more persistent erythema and more persistent pigmentation than either the A/HI or the NHPI group. This indicates that photo-adaptation to a more UV-rich environment may lead to faster recovery in the two Hawaiian groups. Studies like ours can provide further insight into the differences in the risks from UV exposure and, perhaps, skin cancer incidence among people of different R/E backgrounds and of similar R/E groups living in different UV environments.

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Figure 1.
Emission spectra of the UV sources used in Hawai'i and Maryland.

Figure 2.

Top to bottom are photographs of study areas (2×2 cm) of NHPI, A/HI and A/MD volunteers, respectively.

Figure 3.
MPD and MED values show that the majority of subjects had higher MPD values.

Figure 4.

Post-UV-exposure changes in oxyhemoglobin levels. The difference of the apparent oxyhemoglobin level of the control sites from those of the study sites on Day1, 2, 8, and 16 is shown.

Figure 5.

Post-UV-exposure changes in melanin levels. The difference of the apparent melanin level of the control sites from those of the study sites on Day1, 2, 8, and 16 is shown.

Table 1

The characteristics of subjects used in this study and the measured parameters: skin lightness (L*), melanin content in the skin by DRS, MED, and MPD.

Subject	R/E	Sex	Age	Phototype	L*	Melanin Content	MED (SED)	MMD (SED)
H1	A/HI	M	46	3	53.4	1.3	3.75	5.25
H3	A/HI	F	26	3	67	0.42	4.30	6.05
H4	A/HI	M	22	3	61.8	1.02	2.80	3.90
H5	A/HI	F	21	3	67.8	0.38	4.10	4.10
H6	A/HI	M	20	3	53.4	1.01	2.90	4.05
H7	A/HI	F	21	3.5	62.7	0.86	4.20	4.20
H8	A/HI	M	52	4.5	52.5	1.71	6.90	6.90
H9	A/HI	M	22	3	63.4	0.73	2.45	3.50
H10	A/HI	F	37	4	60	0.84	4.20	4.20
H13	A/HI	M	18	3.5	58.1	1.15	2.70	3.85
H15	A/HI	M	35	4	48.5	2.01	3.20	4.60
H19	A/HI	M	48	3.5	60.4	1.37	7.65	7.65
H22	A/HI	F	27	3	69.9	0.15	2.20	3.10
H23	A/HI	M	24	4	57.3	1.24	6.10	6.10
H2	NHPI	F	22	3.5	61.4	0.88	6.20	8.85
H11	NHPI	F	35	4	56.8	1.19	3.70	5.25
H12	NHPI	M	20	4	49.5	1.59	5.60	7.85
H14	NHPI	M	25	4.5	57.8	1.08	4.10	4.10
H16	NHPI	M	24	4	59.5	1.18	3.15	4.50
H17	NHPI	M	23	4.5	54	1.62	4.50	ND
H18	NHPI	M	32	4.5	55.6	1.24	6.35	6.35
H20	NHPI	F	34	4.5	56.2	0.62	4.50	4.50
H21	NHPI	M	51	4.5	57.4	1.13	4.90	6.85
H24	NHPI	F	20	4	60.8	0.88	7.25	7.25
H25	NHPI	M	26	4.5	49.9	1.93	9.05	12.65
H26	NHPI	M	19	4.5	51.9	1.81	6.35	9.05
S1	A/MD	M	61	4	ND	0.72	4.20	6.00
S5	A/MD	M	61	2.5	65.7	0.58	3.00	3.00
S16	A/MD	F	46	2.5	69.1	0.32	3.50	3.50
S21	A/MD	M	30	3.5	58.2	1.24	5.13	6.93
S22	A/MD	F	61	3	67.3	0.42	4.00	4.00
S47	A/MD	F	45	2.5	63.8	0.69	5.80	6.74
S69	A/MD	F	41	2.5	65.4	0.59	3.84	5.56
S82	A/MD	F	36	4	63.4	0.89	4.00	4.00
S91	A/MD	M	65	3	65.9	0.53	4.33	6.21
S95	A/MD	F	65	4	68	0.46	4.72	6.66
S98	A/MD	F	33	3.5	67.4	0.49	2.80	4.00
S99	A/MD	F	59	3.5	66	0.47	3.60	4.20

¹The MED values for S5 were rechecked, hence they are different in (Tadokoro et al., 2003) than here.

²ND, not done.

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Table 2

Basic characteristics and UV responses of unexposed skin in the 3 study groups: raw mean values (standard deviation), [range]

R/E Group	NHPI (n=12)	A/HI (n=14)	A/MD (n=12)
Phototype ¹	4.5 (1.0) [3.5 – 4.5]	3.25 (1.5) [3.0 – 4.5]	3.25 (1.5) [2.5 – 4.0]
L* ²	55.9 (3.9) [49.5 – 61.4]	59.7 (6.3) [48.5 – 69.9]	65.5 (3.0) [58.2 – 69.1]
Melanin Content (a.u.) ²	1.26 (0.40) [0.62 – 1.93]	1.01 (0.51) [0.15 – 2.01]	0.62 (0.25) [0.32 – 1.24]
Oxy-Hb (a.u.) ²	0.68 (0.26) [0.27 – 1.08]	0.54 (0.19) [0.34 – 1.03]	0.37 (0.15) [0.17 – 0.66]
MED (SED) ³	5.47 (1.67) [3.15 – 9.05]	4.10 (1.68) [2.20 – 7.65]	4.08 (0.85) [2.80 – 5.80]
MPD (SED) ³	7.02 (2.54) [4.10 – 12.65]	4.82 (1.36) [3.10 – 7.65]	5.07 (1.42) [3.00 – 6.93]

¹The median and range are reported for phototype, not the mean and SD.

²The L*, melanin content, and Oxy-Hb values were determined at day 0 pre UV exposure.

³The MED and MPD values were determined at day 1 and day 8 post UV exposure, respectively.