Comparison of Skin Biomechanics and Skin Color in Puerto Rican and Non-Puerto Rican Women

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Objective: Skin biomechanics are physical properties that protect the body from injury. Little is known about differences in skin biomechanics in racial/ethnic groups and the role of skin color in these differences. The purpose of this study was to determine the relationship between skin biomechanics (viscoelasticity, hydration) and skin color, when controlling for demographic and health-related variables in a sample of Puerto Rican and non-Puerto Rican women.

Methods: We performed a secondary analysis of data from 545 women in a longitudinal, observational study of skin injury in Puerto Rico and the United States. Data included measures of skin viscoelasticity, skin hydration, skin color, demographic, and health-related variables. Skin color was measured by spectrophotometry (L* - lightness/darkness, a*- redness/greenness, b* - yellowness/blueness). The sample was 12.5% Puerto Rican, 27.3% non-Puerto Rican Latina, 28.8% Black, 28.6% White, and 2.8% Other.

Results: Regression analyses showed that: 1) higher levels of skin viscoelasticity were associated with lower age, higher BMI, and identifying as non-Puerto Rican Latina as compared to Puerto Rican; (all p < .001); and 2) higher levels of hydration were associated with lower L* values, higher health status, lower BMI, and identifying as non-Puerto Rican Latina, White, or Other as compared to Puerto Rican (all p < .05).

Conclusion: When adjusting for skin color, Puerto Rican women had lower viscoelasticity and hydration as compared to other groups. Puerto Rican women may be at long-term risk for skin alterations, including pressure injury, as they age or become chronically ill. [*P R Health Sci J 2019;38:170-175*]

Key words: Skin viscoelasticity, Skin hydration, Puerto Rican women's health

Over the lifespan, the biomechanical properties of the skin change as a result of clinical conditions such as diabetes mellitus (1) and individual differences such as body mass index (BMI) (2) or smoking behaviors (3). Intrinsic changes occur with aging as the skin has decreased ability to regenerate itself (4). Extrinsic changes occur with injury from exposure to solar ultraviolet radiation (UVR) (5), environmental dryness (6), irritants (7), trauma (8,9), and infectious agents (10). Yet a dearth of information exists with respect to biomechanical variations that may occur based on skin color, age, race, and ethnicity, and how these differences potentially affect health-related variables (smoking history, BMI, sun exposure, and health status). Therefore, the aim of this study was to compare skin biomechanics (skin viscoelasticity and hydration) and skin color in Puerto Rican and non-Puerto Rican women when controlling for age, smoking history, BMI, sun exposure, and health status.

Background

Skin biomechanics are the unique biological, physical, and chemical properties that allow the skin to protect and conform as a covering to the body (11,12). Skin biomechanics resist the loss of skin integrity that occurs with movement, stretching, and application of force, thereby giving shape and elasticity to the tissues and resistance to deformity (11-13). The focus of this paper is on two biomechanical properties of the skin: skin viscoelasticity and skin hydration, and how they relate to skin color in a diverse sample of women. Skin color was included as

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a variable because several studies have shown that skin color as well as race/ethnicity may be a source of health disparities related to skin injury in some groups (8,14). The study, derived from a pre-existing data set that included Puerto-Rican and non-Puerto Rican women, provides an opportunity to study the role of race and ethnicity in skin health.

Skin Viscoelasticity and Hydration

Viscoelasticity has two components. Elasticity is the tendency of solid materials to return to their original shape and size after the application of force (11). Viscosity is a measure of a fluid's resistance to flow when a shearing force or stress is applied to the fluid. Skin viscoelasticity combines the water content of the skin with its elastic properties. As compared to elasticity alone, viscoelasticity protects the skin against injury and allows for additional movement away from and returning to its original shape without tearing or breaking (12,13).

Skin hydration, defined as the water content of the stratum corneum (SC, outermost layer of the skin), has three primary functions. As with viscoelasticity, water maintains the plasticity of the skin, thereby protecting it from damage. Water also allows hydrolyzing enzymes to maintain skin health. Finally, skin hydration contributes to the barrier function of the skin as the SC serves as a protective layer to decrease water loss to the environment and block entry of environmental substances into the body (15,16). Because viscoelasticity and skin hydration can be affected by age (17), smoking history (18), BMI (17), sun exposure (19), and health status (11), these health-related variables require consideration during skin studies.

Biomechanical Properties of the Skin and Race/Ethnicity

Little is known if biomechanical differences occur in skin mechanics across races/ethnicities. Early work in this area was done by Weigand, Haygood, and Gaylor, who found that that number of tape strips required to remove the SC was significantly higher in Black than White subjects ($p<0.01$). They concluded that not only did Blacks have more layers in their SC (mean 21.87, min/max 19/27) than do Whites (mean 16.7, min/max 13/20), but they also had heavier SC weight and density (20). The investigators also noted that the range and mean of skin thickness was essentially equal in the two groups. Beradesca and colleagues found racial/ethnic differences among White, Black, and Hispanic/Latino samples with respect to skin conductance, skin thickness, extensibility, elastic recovery, and viscoelasticity, but the long-term clinical ramifications were unexplored. They concluded that, with respect to race and ethnicity, "much remains to be done to understand the various mechanisms underlying the different clinical expressions" that may occur in diverse groups (p. 671) (21). Since that time, further work on skin viscoelasticity and hydration across several populations has been completed (22-26), but investigators have used small and/or homogeneous samples of White, Black, and/or Asian groups.

Methods

We performed a secondary analysis of data from a longitudinal, observational study of skin injury in women. In the primary study, a community sample of healthy women 21 years or older were enrolled in a protocol that included baseline measures of skin viscoelasticity, skin hydration, skin color, and demographic (race/ethnicity and age) and health-related variables (smoking history, BMI, sun exposure, and health status.) We used a representative sampling technique in order to match the distributions of race/ethnicity and age from an emergency department injury registry. The prospective work was approved by the affiliated universities' institutional review boards, all subjects signed informed consent, and all data were de-identified. All subjects received an explanation of study procedures in either Spanish or English. Data were collected in San Juan, Puerto Rico and Philadelphia, Pennsylvania, USA.

Measures

Measurements of skin viscoelasticity were made non-invasively with a Cutometer® MPA 580 (Courage + Khazaka electronic GmbH, Kőln, Germany). We used a 5-second application of vacuum of 400 mbar, followed by a 5 second relaxation period. We completed three readings using a probe with a 2mm aperture at the upper inner arm at a location equidistant between the elbow and shoulder. The cutometer probe exerts a negative pressure on a defined area of skin surface and provides measures of biological elasticity (R7), the ratio of elastic recovery and elastic deformation (17,27,28). A higher value indicates more elastic skin (17). The cutometer is widely viewed as the gold standard (or close to a gold standard) measurement of skin elasticity (17,29-31).

Measurements of skin hydration were made with a Corneometer® CM 825 (Courage + Khazaka electronic GmbH, Kőln, Germany). The corneometer is used non-invasively to determine skin capacitance and reflects the water content of the superficial epidermal layers down to a depth of approximately .01 to .04mm (32,33). Measurements are based on principle that the dielectric constant of water (eighty one) and other substances (generally less than seven) are very different (32,34,35). The corneometer measurements are expressed as arbitrary units (au) from 0 to 120 (36); very dry skin is characterized as having corneometer units below 30 au, dry skin between 30 and 40 au, and normal skin higher than 40 au (37). The corneometer is considered the gold standard (or close to gold standard) for skin hydration measurement (32,33,38,39). Three measurements of skin hydration were made at the inner upper arm as described above.

Skin color is the result of the selective absorption and scattering of light wavelengths from the dermis of the human body and is affected by a variety of factors such as melanin, hemoglobin, and carotene (40). For each subject, three skin color measurements were taken with a hand-held spectrophotometer (Color Tec-PSM hand-held spectrophotometer, Clinton, NJ, USA) at the inner upper arm as described above. The instrument was calibrated at the factory and again during quality control procedures prior to each data collection session with black and white standard controls. We measured constitutive (genetically determined natural, untanned) skin color using the values L*a*b* as defined as follows: value L* represented lightness/darkness (extends from 0 [black] to 100 [white]), value a* represented redness/greenness (positive a* is red and negative a* is green), and value b* represented yellowness/blueness (positive b* is yellow and negative b* is blue). Skin color L* values generally range between 25 (dark) and 70 (light); skin redness (a*) values usually range from +1 to +30, and skin yellowness (b*) values from +5 to +40 (40-42). The type of spectrophotometer used in this study is recognized as the gold standard for skin color measurements (41,42).

A number of self-reported demographic and health-related variables were collected using a questionnaire from previously funded work (8,43). Demographic variables included age and race/ethnicity, using the following classifications: Puerto Rican, non-Puerto Rican Hispanic/Latina, Black, White, and other race/ethnicity. Smoking status was determined by the following question: In the past 6 months, on the average, how many cigarettes/tobacco do you smoke/use a day? Participants had height and weight measured in a skin science laboratory to determine BMI. Sun exposure was determined by the following question: In the past 12 months, how many times did you have a red, blistering, or painful sunburn that lasted a day or more? Health status was determined by the following question: Using a scale of 1 to 10, where 1 is poor health and 10 is excellent health, how would you rate your general health? (8,43).

Statistical analysis

The final sample included 545 women. The cigarette/tobacco variable was transformed into smoking/using (yes/no) in the last 6 months. The sun exposure variable was transformed into sunburn (yes/no) in the last 12 months. Differences in age, BMI, health status, and skin characteristics were compared between the Puerto Rican group and each of the other race/ethnicity groups using ANOVA (continuous variables) and chi-square tests (categorical variables) for the full sample of 545 subjects.

A large number of participants were missing data on sunburn and skin hydration due to inclusion of these measures later in the study. Therefore, only women with complete data were included in our analyses (N=341). A series of two multiple regression models were conducted in order to understand the effect of skin color (L*, a*, b* values), demographic, and health-related factors (smoking history, BMI, sun exposure, and health status) on biomechanical indicators of skin hydration and skin viscoelasticity. Statistical analyses were conducted using R (version 3.2.2) (44). Post-hoc comparisons were made only following significant omnibus tests and, therefore, no correction to the alpha-level was made to reduce chance of type I error.

Results

Table 1 presents a summary of the demographic and health-related characteristics of the sample. The racial/ethnic composition of the sample was 12.5% Puerto Rican (N=68), 27.3% non-Puerto Rican Hispanic/Latina (N=149), 28.8% Black (N=157), 28.6% White (N=156), and 2.8% other race/ethnicity (N=15). The average age was 32.6 years (SD=9.63), which did not vary significantly across groups. There was also no significant difference in health status across groups. However, average BMI was significantly higher among Puerto Rican subjects relative to White subjects (28.1 versus 25.9; $p < .05$). Puerto Rican subjects were more likely to report having experienced a sunburn in the last 12 months relative to both non-Puerto Rican Hispanic/Latina and Black subjects (36.8% versus 12.7% and 3.4%, respectively; all $p < .001$). Puerto Rican subjects were less likely to report smoking or using tobacco in the last 6 months relative to non-Puerto Rican Hispanic/Latina, Black, and White subjects (7.4% versus 29.5%, 31.8%, and 23.1%, respectively; all $p < .001$).

Skin viscoelasticity, hydration, and color

Skin viscoelasticity, hydration, and color characteristics are also presented in Table 1. Values of skin viscoelasticity

Table 1. Demographic, Health-related, Skin biomechanics (Hydration and Viscoelasticity), and Skin color characteristics stratified by race/ethnicity (N=545)

Variable (n missing observations)	Puerto Rican N=68 (12.5%)	Non-Puerto Rican Hispanic N=149 (27.3%)	Black N=157 (28.8%)	White N=156 (28.6%)	Other N=15 (2.8%)
Age (0)	33.41 (10.42)	31.73 (8.59)	34.55 (10.79)	31.25 (8.81)	31.25 (8.63)
Health Status (1)	8.72 (1.26)	8.69 (1.16)	8.59 (1.33)	8.63 (0.95)	8.67 (1.23)
Body Mass Index (115)	28.08 (7.81)	29.47 (8.05)	31.19 (8.64)	25.92 (7.13)	27.56 (7.88)
Any Sunburn Last 12 Months (140)	25 (36.8%)	17 (12.7%)	3 (3.4%)	38 (37.3%)	3 (25.0%)
Smoked Last 6 Months (0)	5 (7.4%)	44 (29.5%)	50 (31.8%)	36 (23.1%)	1 (6.7%)
Skin Hydration (201)	28.92 (6.74)	32.60 (9.70)	35.48 (10.80)	34.54 (9.03)	35.93 (9.22)
Viscoelasticity (3)	61.88 (7.21)	68.72 (8.98)	66.49 (8.37)	62.29 (9.23)	66.58 (4.45)
L* value (1)	58.59 (6.03)	54.60 (7.33)	42.96 (6.53)	64.99 (3.80)	54.11 (10.20)
a* value (1)	8.37 (1.51)	9.47 (1.61)	10.03 (0.90)	7.48 (1.45)	9.46 (1.44)
b* value (1)	19.60 (2.10)	20.51 (2.62)	19.76 (2.58)	17.88 (2.67)	20.10 (2.52)

Note: Values represent M (SD) or N (%). Bold indicates statistically significant differences between a given race/ethnic group and the Puerto Rican group of at least $p < .05$.

were significantly lower among Puerto Rican relative to non-Puerto Rican Hispanic/Latina, Black, and Other race/ethnicity subjects (61.9 versus 68.7, 66.5, and 66.6, respectively; all $p < .05$). Puerto Rican subjects had significantly lower values of skin hydration than Black, non-Puerto Rican Hispanic/Latina, and White subjects (28.9 versus 35.5, 32.6, and 34.5, respectively; all $p < .01$). Puerto Rican subjects had L* value skin color measurements significantly higher (increased lightness) than those for both non-Puerto Rican Hispanic/Latina and Black subjects (58.6 versus 54.6 and 43.0, respectively; all $p < .05$), but significantly lower (decreased lightness) than those for White subjects (65.0). The value of a* skin color measurements among Puerto Rican subjects were significantly higher than those of White subjects (8.4 versus 7.5; $p < .05$), but significantly lower than non-Puerto Rican Hispanic/Latina, Black, or subjects of other races/ethnicities (8.4 versus 9.5, 10.0, and 9.5, respectively; all $p < .05$). The b* value skin color measurements among Puerto Rican subjects were significantly higher than those of White subjects (19.6 versus 17.9; $p < .05$), but significantly lower than those for non-Puerto Rican Hispanic/Latina subjects (19.6 versus 20.5; $p < .05$).

Table 2. Relationship between skin biomechanics (Hydration and Viscoelasticity) and demographic, Health-related, and Skin color variables (N=341).

	Skin hydration				Skin viscoelasticity			
Independent variables	**B**	**SE**	**t-test**	**p-value**	**B**	**SE**	**t-test**	**p-value**
Race/Ethnicity (PR=reference)								
Hispanic (non-PR)	3.45	1.46	2.36	0.019	6.07	1.23	4.95	<0.001
White	5.73	1.57	3.64	<0.001	0.73	1.31	0.55	0.582
Black	3.30	2.21	1.50	0.136	1.85	1.85	1.00	0.317
Other	6.41	3.18	2.02	0.044	4.10	2.66	1.54	0.124
Age	0.07	0.05	1.32	0.189	-0.44	0.04	-10.10	<0.001
Health status	0.99	0.43	2.32	0.021	0.33	0.36	0.92	0.359
Body mass index	-0.31	0.07	-4.59	<0.001	0.32	0.06	5.59	<0.001
Any sunburn last 12 months	1.97	1.24	1.60	0.111	-0.35	1.04	-0.34	0.736
Smoked last 6 months	1.77	1.18	1.49	0.137	-0.61	0.99	-0.62	0.539
Skin color L* value	-2.64	1.18	-2.24	0.026	-1.22	0.99	-1.24	0.217
Skin color a* value	-0.96	0.89	-1.08	0.279	-0.80	0.74	-1.08	0.281
Skin color b* value	0.35	0.59	0.59	0.555	0.68	0.50	1.37	0.172

Note: PR = Puerto Rican. Bold indicates statistical significance ($p< .05$).

Factors related to skin hydration

Table 2 shows the results of the regression of skin hydration on demographic, health-related, and skin color variables. Approximately 16% of the variation in skin hydration was accounted for collectively by these variables. Non-Puerto Rican Hispanic/Latina, Black, and women of other ethnicities/races had significantly higher levels of skin hydration than Puerto Rican women (all $p < .05$). Higher health status was associated with greater skin hydration ($p < .05$), while both higher BMI and higher L-values were associated with lower levels of skin hydration ($p < .05$).

Factors related to skin viscoelasticity

Table 2 also shows the results of the regression of skin viscoelasticity on demographic, health-related, and skin color variables. Approximately 39% of the variation in skin viscoelasticity was accounted for collectively by these variables. Non-Puerto Rican Hispanic/Latina women had significantly higher levels of skin viscoelasticity than Puerto Rican women ($p < .001$). Increased age was significantly associated with lower levels of skin viscoelasticity ($p < .001$) and a higher BMI was significantly associated with higher levels of skin viscoelasticity ($p < .001$).

Discussion

We compared skin biomechanics and skin color in Puerto Rican and non-Puerto Rican women and found that both skin viscoelasticity and hydration were significantly lower in Puerto Rican women than in other groups. These findings suggest that Puerto Rican women may have decreased skin protection and resiliency (4,11) as compared to other groups. There are several explanations for this finding. The Puerto Rican sample was enrolled in San Juan, Puerto Rico, as compared to the enrollment of all other groups in Philadelphia, Pennsylvania, a city in northeastern USA. Therefore, the lifetime exposure to UVR in the Puerto Rican sample was likely higher than women of other racial and ethnic origins, resulting in decreased skin viscoelasticity and hydration (11,45). This explanation is supported by the increased proportion of Puerto Rican women who experienced sunburn in the last 12 months, as compared to the Black and non-Puerto Rican Hispanic/Latina groups. While the differences in skin viscoelasticity and hydration also might be grounded in genetic differences, we could find no support for that explanation in the literature. While age has been found across a number of studies to reduce both skin viscoelasticity and hydration (4,11,17), our groups did not vary by age (see Table 1). Therefore, group differences in age did not account for group differences in skin viscoelasticity and hydration.

Puerto Rican subjects had lower L* (lightness) values and higher yellowness (a*) and redness (b*) values as compared to White subjects and similarly higher L* values and lower a* and b* values as compared to Black and non-Puerto Rican subjects. While we found that skin viscoelasticity and hydration were significantly lower in Puerto Rican women as compared to other groups, these findings were not related to skin color. The results demonstrating the association of skin viscoelasticity and hydration with BMI are puzzling. We found that higher levels of viscoelasticity were associated with higher BMI. Increased BMI is generally associated with decreased viscoelasticity because as people gain weight, the subcutaneous adipose layer thickens and elastic deformation decreases (2,46). It is unclear why viscoelasticity and BMI were positively associated and skin hydration and BMI were negatively associated in our sample.

Several findings inform skin science, public health, and our understanding of differences among racial and ethnic groups. Our Puerto Rican sample had higher rates of sunburn in the previous 12 months than the other groups. Given that all of them lived in a tropical climate, additional public health initiatives in Puerto Rico on the need for UVR protection are warranted. Sun exposure may also have led to reduced levels of viscoelasticity noted in the Puerto Rican sample as compared to the other groups (61.9 versus 68.7, 66.5, and 66.6, respectively). Sun exposure, decreased viscoelasticity, and decreased skin hydration are related to skin damage and wrinkle formation (4,25) and may present long term risk to Puerto Rican women for skin impairment. In contrast, the Puerto Rican sample demonstrated some health benefits. They had a low prevalence of cigarette smoking/tobacco use as compared to women of all races/ethnicities enrolled in Philadelphia except for the Other group. These findings replicate national statistics reported by the Centers for Disease Control and Prevention, which reports a smoking prevalence of 19.1% in Philadelphia and 7.7% in Puerto Rico (47).

Measurement error has the potential to limit our findings. In spite of quality control for our instruments, measurement error may have occurred in the skin viscoelasticity, hydration, and color variables. Because we performed the study in Puerto Rico and the US, the two locations may have contributed geographic bias to our findings. Response bias may have occurred with our self-reported measures of smoking history/tobacco use, sun exposure, and health status. Our study methods were observational in nature and did not allow us to determine causality among our variables, including sun exposure and skin biomechanics. Finally, our study findings are not applicable to males.

Conclusion

Limited work has been done in the skin science field attempting to understand differences in skin biomechanics based on skin color, demographic and health-related variables. In a racially and ethnically diverse sample of women, Puerto Rican women had decreased skin viscoelasticity and hydration as compared to other groups, when controlling for skin color and other variables. The biomechanical properties of the skin have protective functions associated with long term health. Therefore, Puerto Rican women as compared to other groups may be at long-term risk for alterations in their skin, including pressure injury, as they age or become chronically ill.

Resumen

Objetivo: La biomecánica de la piel son propiedades físicas que protegen al cuerpo de lesiones mecánicas, químicas y radiantes. Poco se sabe sobre las diferencias en la biomecánica de la piel en grupos raciales / étnicos y la importancia del color de la piel en estas diferencias. El propósito fue determinar la relación entre la biomecánica y el color de la piel en una muestra de puertorriqueñas y no puertorriqueñas. Métodos: Se realizó un análisis secundario longitudinal observacional de lesiones cutáneas en 545 mujeres en PR y EEUU. Los datos incluyeron medidas de viscoelasticidad, hidratación y color de la piel, exposición al sol y variables relacionadas con la salud. El color se midió por espectrofotometría (L * - claridad / oscuridad, a * - enrojecimiento / verdor, b * - amarillez / azul). Resultados: El análisis de regresión mostró: 1) los niveles más altos de viscoelasticidad se asociaron con una edad más baja, un IMB más alto y la identificación como latina no puertorriqueña en comparación con la puertorriqueña y 2) niveles más altos de hidratación se asociaron con los valores más bajos de L *, un estado de salud más alto, un IMB más bajo y la identificación como latina no blanca puertorriqueña, blanca u otra en comparación con la puertorriqueña. Conclusiones: Al ajustar el color de la piel, las puertorriqueñas tenían una menor viscoelasticidad e hidratación en comparación con otros grupos. Las puertorriqueñas pueden tener un riesgo a largo plazo de sufrir alteraciones en la piel.

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