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Sun Protection by Beach Umbrella vs Sunscreen With a High Sun Protection Factor
A Randomized Clinical Trial

Hao Ou-Yang, PhD; Lily I. Jiang, PhD; Karen Meyer, BS; Steve Q. Wang, MD; Aaron S. Farberg, MD; Darrell S. Rigel, MD

Supplemental content

IMPORTANCE Sun-protective behavior affects skin cancer prevention. Shade works by physically shielding skin from direct harmful UV rays; however, skin may still remain exposed to reflected and indirect UV rays. There is no current standard metric to evaluate shade for its effectiveness in sun protection, and there is insufficient clinical evidence that a beach umbrella alone can provide adequate sun protection.

OBJECTIVE To directly measure sunburn protection offered by a standard beach umbrella compared with that provided by sunscreen with a high sun protection factor under actual use conditions.

DESIGN, SETTING, AND PARTICIPANTS A single-center, evaluator-blinded, randomized clinical study was conducted from August 13 to 15, 2014, in Lake Lewisville, Texas (elevation, 159 m above sea level), among 81 participants with Fitzpatrick skin types I (n = 1), II (n = 42), and III (n = 38). Participants were randomly assigned to 2 groups: 1 using only a beach umbrella, and the other using only sunscreen with a sun protection factor of 100. All participants remained at a sunny beach for 3½ hours at midday. Clinical sunburn evaluation of each individual for all exposed body sites was conducted 22 to 24 hours after sun exposure.

INTERVENTIONS The shade provided by a beach umbrella or protection provided by sunscreen with a sun protection factor of 100.

MAIN OUTCOMES AND MEASURES Sunburn on all exposed body sites 22 to 24 hours after sun exposure.

RESULTS Among the 81 participants (25 male and 56 female; mean [SD] age, 41 [16] years) for all body sites evaluated (face, back of neck, upper chest, arms, and legs), the umbrella group showed a statistically significant increase in clinical sunburn scores compared with baseline and had higher postexposure global scores than the sunscreen group (0.75 vs 0.05; $P < .001$). There was a total of 142 sunburn incidences in the umbrella group vs 17 in the sunscreen group. Thirty-two of the 41 participants (78%) in the umbrella group showed erythema in 1 or more sites vs 10 of the 40 participants (25%) in the sunscreen group ($P < .001$). Neither umbrella nor sunscreen alone completely prevented sunburn.

CONCLUSIONS AND RELEVANCE A beach umbrella alone may not provide sufficient protection for extended UV exposure. It is important to educate the public that combining multiple sun protection measures may be needed to achieve optimal protection.

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Author Affiliations: Johnson & Johnson Consumer Inc, Skillman, New Jersey (Ou-Yang, Meyer); Thomas J. Stephens & Associates, Richardson, Texas (Jiang); Department of Dermatology, Memorial Sloan Kettering Cancer Center, Basking Ridge, New Jersey (Wang); Department of Dermatology, Icahn School of Medicine at Mount Sinai, New York, New York (Farberg); Department of Dermatology, New York University School of Medicine, New York (Rigel).

Corresponding Author: Hao Ou-Yang, PhD, Johnson & Johnson Consumer Inc, 199 Grandview Rd, Skillman, NJ 08558 (houyan4@its.jnj.com).

Seeking shade is widely practiced to avoid direct sun exposure to exposed skin.[1] Unlike UV-protective clothing, shade typically does not block all the angles through which UV light can reach skin. Different types of shade vary in their protectiveness owing to differences in materials, size, and variations in environmental UV conditions (eg, solar angle, time of day, season, and location).[2-8] Some widely used shading devices, such as beach umbrellas, may have high UV protection factor ratings but do not protect skin from UV rays whose angles of approach are diffused by atmospheric particles or reflected from the ground. People often assume that their skin is fully protected as long as they are under the shade of an umbrella. On the other hand, there are few clinical studies that specifically evaluate the UV protectiveness of a beach umbrella or directly compare it with protection provided by sunscreen with a high sun protection factor (SPF).

We conducted a single-center, evaluator-blinded, randomized clinical study to compare the sunburn protection effects of a beach umbrella vs a high-SPF sunscreen side by side in a beach setting under actual use conditions.

Key Points

Questions How well does typical shade from a beach umbrella protect against sunburn and how does it compare with protection provided by sunscreen with a high SPF?

Findings This single-center, randomized clinical study found that, during 3½ hours of sun exposure, 78% of participants under shade from a beach umbrella developed a sunburn vs 25% of participants using sunscreen. Neither shade nor sunscreen alone completely prevented sunburn.

Meaning Shade from a beach umbrella alone does not provide sufficient protection for extended exposure to UV rays; indicating a combination approach may be needed for optimal protection from UV rays.

Table 1. Amount of Sunscreen Used in the Sunscreen Group

Characteristic	Mean (SD) [range]
Application, g	
Initial	15.8 (8.6) [4.5-41.5]
Total	29.6 (16.6) [9.1-72.9]
Reapplications, No.	2.3 (1.1) [0-4]

Methods

The study was conducted from August 13 to 15, 2014, at Lake Lewisville, Texas (altitude, 159 m above sea level). A commercially available beach umbrella (JGR Copa LLC; round-shaped, 203 cm diameter, and 190 cm high) was selected for the study because the height and size are typical of what is commonly used at the beach. Transmission of UV rays through the umbrella material was measured with a spectrophotometer, and no detectable transmittance was found across the entire UV spectrum.

Sunscreen lotion with an SPF of 100 (Neutrogena Ultra Sheer SPF 100+, Neutrogena Corp) was used. UV-A protection factor measured via the Japan Cosmetic Industry Association UV-A test method[9] was more than 33. This sunscreen was tested to be water resistant for 80 minutes per the 2011 US Food and Drug Administration monograph[10] and was determined to be photostable.

The full study protocol is available in the Supplement. The study was approved by the IntegReview Institutional Review Board (Austin, Texas), and written informed consent was obtained. Participants with a history of skin conditions, including phototoxic and photoallergic reactions, that could interfere with the study were excluded. At baseline, 7 exposed skin areas (face, upper chest, back of the neck, both arms, and both legs) were clinically examined. Only participants with no presence of sunburn on any exposed areas were enrolled. A total of 92 individuals were enrolled in the study. Participants were randomly assigned to either the sunscreen or umbrella group according to the predetermined randomization schedule. The randomization number was assigned sequentially in ascending order in the order of enrollment into the study. Once a randomization number has been assigned to a participant, it cannot be reassigned to another participant.

Participants in the sunscreen group were given preweighed tubes of sunscreen. They were instructed to apply the product liberally to all exposed areas of skin 15 minutes before beach exposure and were instructed to reapply the sunscreen at least every 2 hours or as needed following the directions on the label. Total amount of sunscreen used was recorded. Participants were instructed to stay at the beach for 3½ hours between 10 AM and 2 PM, but they could leave or stay under a shade for up to 30 minutes for cooling or rest. Sweating was not monitored, but participants were instructed to reapply sunscreen after sweating.

Participants in the umbrella group were instructed to stay under the umbrella without wearing clothes that could block the evaluated areas during the duration of the study. They were allowed to leave the umbrella for up to 30 minutes after covering up. Positioning under the umbrella was monitored and adjusted as the solar angle changed to minimize any direct exposure of UV rays to evaluated areas.

Participants could not engage in water activities and were placed at least 33 m away from the water. Time away from the beach was recorded. Sun exposure was avoided after the conclusion of the study until evaluation.

Intensities of UV rays during the study period (between 10 AM and 2 PM) were monitored. Total accumulated dose of UV radiation was more than 15 minimal erythema doses under temperatures of 24° to 32°C and humidity of 35% to 55%. UV reflectance measurement from the sand revealed a ground albedo of 7% to 9%.[11]

All participants were evaluated clinically for sunburn by a clinician who was blinded to the randomization 22 to 24 hours following sun exposure. For each exposed area, a score of 0 to 4 was given, where 0 indicates no sunburn; 1, possible sunburn, not clearly defined; 2, defined redness clearly caused by UV rays; 3, severe sunburn with pronounced redness; and 4, edema and/or blisters.

Table 2. Postexposure Clinical Sunburn Evaluation Findings for Each Exposed Body Site and Global Average Score[a]

			Postexposure Score		*P* Value	
Exposed Site and Group	Participants, No.	Participants With Worsened Score, No.	Mean	Median (IQR)	Postexposure vs Baseline[b]	Between the 2 Groups[c]
Face						
Umbrella	41	23	0.83	1 (1.5)	<.001	<.001
Sunscreen	40	7	0.18	0	.02	
Upper chest						
Umbrella	41	27	0.9	1 (1)	<.001	<.001
Sunscreen	40	4	0.08	0	NS	
Back of neck						
Umbrella	41	14	0.33	0 (1)	<.001	<.001
Sunscreen	40	0	0	0	NS	
Right arm						
Umbrella	41	23	0.82	1 (1)	<.001	<.001
Sunscreen	40	2	0.04	0	NS	
Left arm						
Umbrella	41	23	0.85	1 (1)	<.001	<.001
Sunscreen	40	3	0.06	0	NS	
Right leg						
Umbrella	41	16	0.78	0 (1)	<.001	<.001
Sunscreen	40	1	0.01	0	NS	
Left leg						
Umbrella	41	16	0.71	0 (1)	<.001	<.001
Sunscreen	40	0	0	0	NS	
Global score[d]						
Umbrella	41	32	0.75	0.57 (0.96)	<.001	<.001
Sunscreen	40	10	0.05	0 (0.05)	.002	

Abbreviations: IQR, interquartile range; NS, not significant.

[a] Baseline score = 0.

[b] Calculated from Wilcoxon signed rank test.

[c] Calculated from Wilcoxon rank sum test.

[d] Mean of all sites.

A global sunburn score for each participant was calculated by averaging 7 exposed sites. Preexposure and postexposure scores were compared using the Wilcoxon signed rank test. Intergroup data were compared using the Wilcoxon rank sum test. Sunscreen use and time absent from the beach were analyzed based on tube weight and diaries, respectively. Statistical significance was set at $P = .05$ for both tests.

Results

Eighty-one participants (88%) completed the study (25 male and 56 female), with 40 in the sunscreen group and 41 in the umbrella group. Participants had Fitzpatrick skin types I (n = 1), II (n = 42), and III (n = 38). Eleven participants did not complete the study because they did not attend all scheduled study visits.

Individuals in the sunscreen group initially applied a mean (SD) of 15.8 (8.6) g of sunscreen (range, 4.5-41.5 g) to exposed skin sites, corresponding to a density of approximately 1 mg/cm^2 (representative of actual sunscreen use[12,13]) (**Table 1**). Participants reapplied sunscreen a mean (SD) of 2.3 (1.1) times (range, 0-4) and applied a mean (SD) total of 29.6 (16.6) g of sunscreen (range, 9.1-72.9 g), or approximately 2 mg/cm^2. Twenty-eight individuals in the umbrella group left the beach during the study (mean, 7 minutes) vs 30 participants in the sunscreen group (mean, 11 minutes).

Both groups demonstrated a significant increase in global sunburn scores from baseline (umbrella group, 0.75 vs 0; $P < .001$; and sunscreen group, 0.05 vs 0; $P = .002$) (**Table 2**). The total number of sunburned areas was 142 for the umbrella group and 17 for the sunscreen group.

Participants in the umbrella group had a significant increase in sunburn scores from baseline for all of the body sites examined vs those in the sunscreen group, who had no significant increase in sunburn scores vs baseline for any site except the face (0.18 vs 0; $P = .02$) (Table 2). Global scores increased in 32 participants in the umbrella group (78%) compared with 10 individuals in the sunscreen group (25%). Seventeen participants in the umbrella group had a sunburn score of 2 or more (redness clearly caused by UV rays) on 1 or more sites, while 2 individuals in the sunscreen group had a sunburn score of 2 in the facial area after sun exposure.

Discussion

This study found that shade from a beach umbrella provided less effective sun protection than did a high-SPF sunscreen. Shade, recommended by many groups for prevention of skin cancer, is effective in reducing the amount of exposure to UV rays in general, but the magnitude of reduction and clinical effectiveness may be less than expected.[1-8] The shade provided by a beach umbrella was compared with protection from a high-SPF sunscreen as a benchmark since seeking shade and applying sunscreen are the 2 most popular sun protection measures while at a beach.[12,13]

There is currently no standard metric evaluating the UV protectiveness of shade. One proposal for a shade protection factor calculated the ratio of erythemally weighted UV rays measured horizontally in full sun vs under shade.[14] An ideal shade protection factor would take into account material factors (UV absorption properties of the shade material and coverage size), environmental factors (amount of diffused UV rays and albedo of the ground surface), and human factors (position and orientation under shade).[5,14] Because multiple variables can significantly influence the effectiveness of shade, it remains challenging to quantify how much actual protection a specific shade device would provide in a given situation.

Beach umbrellas, as convenient shade structures that are widely used in summer, are designed to block direct UV rays but do not block scattered or diffused UV rays, which could be significant at places such as a beach. Our study used an umbrella of typical size (in terms of radius and height) with no transmission of UV rays and monitored the participant's behavior under the umbrella throughout the study to ensure there was no direct sun exposure. We found that a beach umbrella reduces the amount of UV light that can reach skin, but the umbrella alone may not provide sufficient protection for extended outdoor exposure. This finding points to the importance of educating the public how to properly select and use shade to maximize protection from UV rays in actual practice. It also suggests that additional sun protection measures (wearing hats and clothing, applying sunscreens, and limiting outdoor exposure time) may also be needed while at the beach.

Limitations

This study has some limitations. Only 1 type of beach umbrella was evaluated in our study. Other shade devices, such as buildings or canopies with different coverage sizes, may provide different levels of protection but are not likely to be very effective unless they are also designed to protect against a majority of the scattered and reflected UV rays.[3-8] Also, participants in the umbrella group were monitored and reminded to adjust their position to ensure optimal coverage in the study. People who do not adjust their position under a beach umbrella may not be as protected.

High-SPF sunscreen provided better protection against sunburn than the beach umbrella, but it did not completely prevent sunburn under actual use conditions. This finding may be especially true for the face, where sweating may be a factor and less sunscreen is generally applied compared with other body sites.[2,15] A sunscreen with an SPF of 100 was used since individuals in the sunscreen group would not be able to use other sun-avoidance measures. A different sunscreen with a lower SPF may result in more sunburn than observed in this study.

Conclusions

This is the first clinical study, to our knowledge, to directly evaluate the efficacy of protection against UV rays of a beach umbrella and compare it with that of a high-SPF sunscreen in a side-by-side trial. Umbrella shade alone may not provide sufficient sun protection during extended exposure to UV rays. Although the SPF 100 sunscreen was more efficacious than the umbrella, neither method alone prevented sunburn completely under actual use conditions, highlighting the importance of using combinations of sun protection practices to optimize protection against UV rays.

ARTICLE INFORMATION

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Study concept and design: Ou-Yang, Wang.
Acquisition, analysis, or interpretation of data: Jiang, Meyer, Farberg, Rigel.
Drafting of the manuscript: Wang, Farberg, Rigel.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Jiang, Farberg, Rigel.
Administrative, technical, or material support: Jiang, Farberg.
Study supervision: Ou-Yang, Wang, Farberg, Rigel.

Conflict of Interest Disclosures: Dr Ou-Yang and Ms Meyer reported being employees of Johnson & Johnson Consumer Inc, the parent company of Neutrogena Corp and manufacturer of the sunscreen tested in this study. Dr Jiang reported being an employee of Thomas J. Stephens & Associates, the independent testing laboratory that received compensation for conducting this study. Drs Wang, Farberg, and Rigel reported serving as consultants for Johnson & Johnson Consumer Inc. No other disclosures were reported.

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NOTABLE NOTES

John Tyndall's Effect on Dermatology

Patricia M. Richey, BS; Scott A. Norton, MD, MPH, MSc

When dermatologists see the muted indigo discoloration of dermal melanosis or an old tattoo, they knowingly murmur *sotto voce*, "Ah, witness the Tyndall effect." But can they explain it?

John Tyndall (1820-1893) was the first to explain why cutaneous hemorrhagic or melanotic lesions, which should appear red-brown or brown-black, respectively, instead appear blue-tinged. Tyndall observed that this phenomenon (**Figure**) occurred only in nonhomogenous media, in which irregularities cause short-wavelength visible light (ie, at the blue end of the spectrum) to scatter, some reflecting back to the observer. Long-wavelength visible light (at the red end of the spectrum) continues to pass through (and ultimately vanish within) the nonhomogenous medium.

This led to a curious experiment that supported the emerging hypothesis of germ theory. Tyndall proved that the airborne particles responsible for scattering light include living organisms, now recognized as bacteria. When he placed food in containers sealed with purified air (ie, air so pure and homogenous that it did not produce a Tyndall effect), the food did not decompose. In contrast, food placed in containers sealed with natural, particle-filled ("Tyndall-ogenic") air soon spoiled. Therefore, he concluded, natural air is full of imperceptible particulate matter, including living organisms, that interfere with and scatter the Sun's visible light.

Tyndall was an experimental physicist in Victorian England. Born into a poor Protestant family in Leighlinbridge, County Carlow, Ireland, he first worked in railway design, but turned to science, obtaining a doctorate from University of Marburg, Germany, studying under Robert Bunsen (inventor of the Bunsen burner).

In 1853, Tyndall became professor of natural philosophy (physics) at the Royal Institution, London, and was renowned for brilliant public lectures and demonstrations, making science accessible to people who otherwise would not encounter it. His Friday Evening Discourses for the Royal Institution's members and guests were formal events that continue today. In 1864, Tyndall and 8 others, including biologist T. H. Huxley, philosopher Herbert Spencer, and botanist J. D. Hooker, formed the "X-Club," which was intended to direct the course of British science and lobby for government largesse.

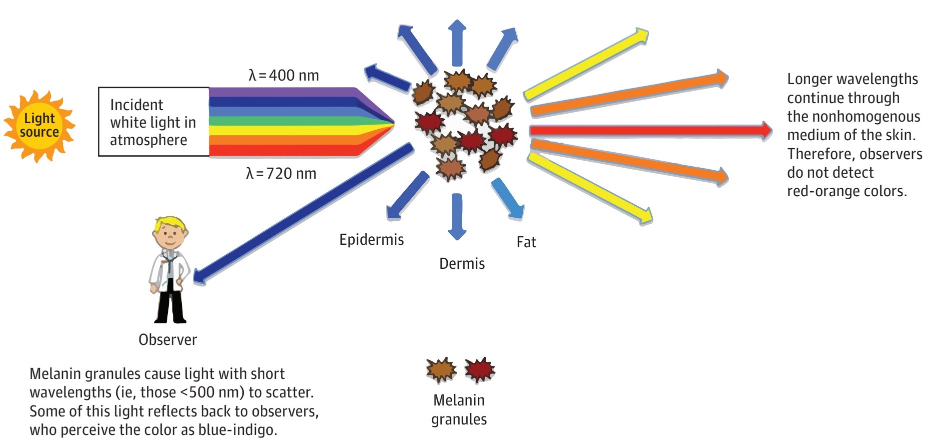
Tyndall was a groundbreaking experimentalist. He constructed the first ratio spectrophotometer, allowing him to measure absorptive powers of natural atmospheric gases. He found that water vapor absorbed radiant heat better than ozone, carbon dioxide, and hydrocarbons—and was therefore the most important gas controlling Earth's surface temperature: the cause of the "greenhouse effect." He later suggested that variations in atmospheric water vapor and carbon dioxide cause climate change.

Unafraid of controversy, he engaged in divisive discussions on everything from spontaneous generation to the efficacy of prayer to Irish Home Rule. In 1874, he was accused of atheistic scientific materialism after stating that cosmology belonged to Science and that physical matter had the power within itself to produce life.

Author Affiliations: Georgetown University School of Medicine, Washington, DC (Richey); Department of Dermatology, Children's National Medical Center, Washington, DC (Norton).

Corresponding Author: Patricia Richey, BS, Georgetown University School of Medicine, 3900 Reservoir Rd NW, Washington, DC 20007 (pmr35@georgetown.edu).

Figure. The Tyndall Effect in the Skin



When visible light enters a nonhomogenous medium, light with wavelengths shorter than the particle diameter will be scattered when it strikes those particles, whereas light with wavelengths longer than the particle diameter continue through the nonhomogenous medium without scattering.