Systematic Review Article

Efficacy, Persistence And Safety of Inorganic vs. Organic Sunscreens: A Narrative Review

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ABSTRACT

As concerns arise regarding skin cancer and photoaging in individuals, understanding the effectiveness of inorganic and organic sunscreen formulations is an essential matter for both healthcare providers and consumers. This literature review analyzes relevant peer-reviewed studies published between the years 2005 and 2024, focusing on matters of efficacy such as overall clinical performance, photostability, user safety, and persistence. Inorganic sunscreens, primarily composed of zinc oxide and titanium dioxide, function by reflecting and scattering UV rays; organic sunscreens, primarily composed of oxybenzone, avobenzone, and octinoxate, absorb UV radiation instead. Findings suggest that, while having different mechanisms, both inorganic and organic sunscreens provide efficient UV protection. Inorganic sunscreens are found to possibly be more safe, persistent and effective for individuals with sensitive skin barriers and prolonged water exposure; organic sunscreens are found to possibly be more effective for individuals expecting minimal water exposure. However, direct comparison between the two sunscreen agents is limited in factors of consumer application and regulated human testing conditions. Despite technological advancements and concern regarding sunscreen efficacy, a gap is still present; a need is highlighted for an increase in controlled standardized clinical trials to assess specific sunscreen efficacy more accurately.

Keywords: Inorganic Sunscreens; Organic Sunscreens; Mineral Sunscreens; Chemical Sunscreens; Ultraviolet (UV) Light; Radiation

INTRODUCTION

According to the American Academy of Dermatology (AAD), skin cancer is the most common form of cancer in the United States, with an estimated one in five Americans being prone to it in their lifetime (1). Considering the frequency of skin cancer in America, attention should be drawn to the urgency of skin protection. The most common way to obtain skin cancer is due to excessive exposure to ultraviolet (UV) radiation, primarily from the sun. The most favored form of protection from skin cancers are sunscreens. Sunscreens are effective at preventing skin damage as they reflect, absorb, and/or scatter UV radiation (2). Specifically, UV-B is the primary cause of skin damage and has a shorter wavelength in nanometers; UV-A penetrates deeper, has longer wavelengths in nanometers, and contributes to photoaging, which is premature aging of the skin due to light exposure (3). The sun protection factor (SPF) is the amount of UV-B radiation that a sunscreen is able to absorb or reflect. The SPF number is inversely related to the

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amount of UV radiation an individual will be exposed to. Essentially, a higher SPF number correlates with a greater degree of protection from UV-B rays (4).

Notably, there are two primary types of sunscreen: inorganic and organic. Inorganic sunscreens, also referred to as physical or mineral sunscreens, have active ingredients of zinc oxide and titanium dioxide (4). Organic sunscreens, or organic sunscreens, primarily have active ingredients of oxybenzone, avobenzone, and octinoxate. These terms are used interchangeably among the studies included; for clarity, this review will refer to the agents as either organic or inorganic. Discussion of each of the sunscreens' active ingredients are crucial as they provide context for their specific mechanisms. Inorganic sunscreens work to physically block radiation, creating a protective layer on the skin to reflect UV rays. The zinc oxide and titanium dioxide serve as tiny mirrors that reflect UV-A and UV-B rays (4). Conversely, organic sunscreens' organic molecules activate to absorb UV radiation. Oxybenzone, a common chemical sunscreen ingredient, absorbs both UV-A and UV-B rays, while avobenzone only absorbs UV-A rays and octinoxate absorbs only UV-B rays. In other words, inorganic sunscreens reflect UV radiation, while organic sunscreens absorb UV radiation.

These differences in mechanisms contribute not only to levels of protection, but also to commercial speculation regarding safety and efficacy. In terms of modern research, a comparison of the efficacy of inorganic and organic sunscreens lacks an abundance of clinical trials. Additionally, a lack of clarity in efficacy among the inorganic and organic sunscreen types emerges. This deficiency in literature leaves consumers wondering which sunscreen type is more effective for preventing or reducing skin damage, especially in different environments, for various skin types, different demographics, and use cases. This literature review aims to address the following question: How do organic and inorganic sunscreens compare in their efficacy and safety? By synthesizing various recent studies and reviews, this research will provide more clarity on how the sunscreens specifically differ in efficacy outcomes as well as safety and composition.

METHODS AND MATERIALS

In efforts to address the research question, this review focuses on synthesizing previous studies and limited clinical studies regarding efficacy and safety of inorganic and organic sunscreens.

The studies were selected with use of structured research search engines, including Google Scholar and PubMed. When using these engines, search terms included the research question or more niche terms such as 'mineral/chemical sunscreen efficacy,' 'mineral/chemical sunscreen clinical trial,' 'organic vs. inorganic sunscreens,' and 'photoprotection.' Boolean operators were able to filter and present studies relevant to the search keywords in the language of English and within the publishing date range of the last two decades, specifically the years 2000-2024.

In order to attribute relevance, studies were included in the literature review if they: were in the language of English (to ensure accurate interpretation), contained quantitative data on inorganic and/or organic sunscreen efficacy, observed results within clinical or simulative laboratory trials, and/or measured appropriate outcomes such as SPF, biomarkers of skin damage, absorption levels of UV-A/UV-B, or qualitative information regarding results of a clinical study. All studies included are manuscripts from scientific peer-reviewed journals.

Contrarily, studies were excluded from the literature review if they: strictly were systematic reviews, lacked measurable outcome data relevant to the research question, studied non-human animals, or did not explicitly state the sunscreen agent type being tested/discussed. This is because the motive of this research paper aimed to draw relevant and beneficial conclusions for humans.

Furthermore, when reviewing potential studies for the review, a brief screening of both the title and abstract were performed. This screening helped to allow for initial relevance, and if criteria was met, a full scan of the study would then follow. A narrative approach, valuing contextualization, was needed to summarize and articulate the main findings of each article regarding efficacy and outcomes incorporating multiple databases.

RESULTS AND DISCUSSION

A total of ten studies were discovered and evaluated in this literature search, focusing on differences in efficacy, persistence, and safety between organic and inorganic sunscreens. These studies are summarized in Table 1.

Efficacy

Even though inorganic and organic sunscreens operate with different mechanisms, some studies suggest

Table 1. Summary of studies included in this review focusing on safety, efficacy, and persistence of inorganic and organic sunscreens

Reference	Sunscreen Type	Characteristic Assessed	Methods	Main findings
Matta *et al* [2019] (2)	Organic	Safety	Clinical trial, 24 volunteer participants split into four groups. Each group tested with a different chemical to measure systemic absorption.	Results indicate that all four of the organic sunscreens tested were absorbed into the participants bloodstream at levels exceeding the FDA threshold.
Lademann *et al* [2005] (5)	Both	Efficacy	*In vitro* study testing sunscreens with inorganic filters, organic filters, and both on experimental skin models.	Results suggest that when inorganic and organic sunscreen filters are combined, a synergistic effect occurs. A higher SPF is measured.
Ezekwe *et al* [2024] (6)	Both	Efficacy	In a clinical trial, 12 volunteers had four different sunscreen variations applied to their back, two relevant ones: one inorganic sunscreen, one organic.	Results indicate that the inorganic sunscreen variation demonstrated the most and higher protection in comparison to the other variations.
Rachmani *et al* [2023] (7)	Both	Persistence	Double-blind, randomized clinical trial testing 22 (aged 18-40) swimmers. Inorganic and organic sunscreens [SPF 30] were applied to separate areas of the body.	Results indicate that the SPF of the inorganic sunscreen remained higher than that of the organic sunscreen after 1.5 hours of water exposure.
Bodekaer *et al* [2008] (8)	Both	Persistence	Clinical trial consisting of 24 volunteers, testing the durability of inorganic and organic sunscreens. Volunteers had seven squares of sunscreen applied to their backs.	Results demonstrate that the SPF of the organic sunscreen reduced more than the inorganic sunscreen over the span of 8 hours. However, the percent decrease remained fairly close in numeric value.
Rouabhia *et al* [2002] (9)	Inorganic	Persistence	*In vitro* study using engineered skin mimicking real human skin. Half of the skin samples were left untreated, while the other half were treated with a physical inorganic sunscreen. Both groups of samples were exposed to UV light.	Results indicate that the untreated skin samples experienced major damage from the UV light, including impaired epidermis, loss of functional proteins, and DNA damage. The treated skin samples did not experience these effects, suggesting that the inorganic sunscreen appropriately protected the skin.
Aburto-Corona *et al* [2016] (10)	Both	Persistence	Randomized clinical trial with a crossover design, testing 20 physically active college students (10 males, 10 females). This study tested two water-resistant sunscreens (one inorganic, one organic) and their effect of sweat rates among the participants.	Results found that the sweat rate was lower with the inorganic sunblock in comparison to the organic sunscreen. This influences persistence in that use of inorganic sunscreens may be more likely to encourage sweat in comparison to organic sunscreens.
Warshaw *et al* [2013] (11)	Organic	Safety	Retrospective analysis including patch testing 23,908 participants (ranging between different genders and ages) with organic sunscreen.	Results found that 219 of the participants had an allergic reaction to a common chemical ingredient within the sunscreen. These results suggest that organic sunscreens may serve as a larger health risk to those with allergies or weak skin barriers.

Continued Table 1. Summary of studies included in this review focusing on safety, efficacy, and persistence of inorganic and organic sunscreens

Reference	Sunscreen Type	Characteristic Assessed	Methods	Main findings
Mohammed *et al* [2019] (12)	Inorganic	Safety	Clinical trial consisting of 5 volunteers, with no active skin damage/disease, ranging from ages 20-30. ZnO-NPs were formulated into an inorganic sunscreen, which was then applied to and monitored over the span of 5 days.	Results indicate that the ZnO-NPs did not penetrate into the viable epidermis nor provoked toxicity. These findings support the safety of inorganic sunscreens as zinc oxide is a common mineral filter used in inorganic sunscreens.
Leite-Silva *et al* [2016] (13)	Inorganic	Safety	*Ex vivo* study using 12 samples of human skin derived from the abdomen simulating impaired skin barriers. Sunscreen treatments were applied to the skin samples, one treated silane-coated ZnO-NPs, and the other treated with uncoated ZnO-NPs.	Results indicate that over 93% of the ZnO-NPs did not travel into the epidermis layers. These findings suggest that inorganic sunscreens containing ZnO-NPs could be safe even for individuals with compromised skin barriers.

that they offer similar measures of protection, and may even be more effective when used together. Lademann *et al*. tested with optical simulations, specifically a Monte Carlo photon transport, and experimental skin models depicting real human skin. Their study was *in vitro* (conducted outside a living organism and laboratory), consisting of testing sunscreens with solely inorganic filters, solely organic filters, and a combination of both in UV protection. Researchers found that when tested alone, the sunscreen simulations functioned as intended; the inorganic sunscreen filters scattered and reflected UV light, while the organic sunscreen filters absorbed the UV light (5). Both inorganic and organic filters were shown to be efficacious alone but possibly stronger when combined. When the filters were tested together, Lademann *et al*. found that the inorganic sunscreen filters scattered the UV rays, allowing more time for the organic sunscreen filters to absorb the UV rays. Researchers claimed this finding as a synergistic effect, allowing for higher SPF and higher blockage of UV radiation (5). This is likely due to more photons being absorbed.The primary limitation of this study in context of the research question is that the study used computer simulations and artificial skin models, which may not be entirely accurate to real human skin. Additionally, the study was conducted under controlled conditions, not considering realistic factors such as sweat or water exposure. The study also measured optical rather than biological behavior damage such as DNA or skin damage, which may not directly correlate with long-term skin damage. Lademann *et al*'s findings allow for a new perspective to emerge in terms of overall efficacy, valuing inorganic and organic sunscreen filters as a whole rather than through comparison.

Another study conducted by Ezekwe *et al*. studied how well different 'products' can protect an individual's skin when exposed to two different lights: UV-A1, a longer wavelength of UV-A that penetrates the skin more deeply (less likely to produce sunburn), and visible light, or sunlight (6). In this clinical study, 12 volunteers had four different sunscreen products applied to their back. The two relevant products tested included an inorganic sunscreen containing titanium dioxide and iron oxides, and a sunscreen containing a combination of inorganic and organic sunscreen filters (6). Researchers assessed for erythema and pigmentation immediately after the irradiation, as well as on days 1, 7, and 14 of the two week study. Results showed that the inorganic sunscreen containing titanium dioxide and iron oxides offered higher and more persistent protection in comparison to the others (6). It is important to note that the sample size of the study was extremely limited in addition to the products tested being limited to specific formulations, limiting generalizability. Additionally, the duration of the study was short-term, failing to account for long term effects such as DNA damage or photoaging.

Collectively, Lademann *et al*.'s findings suggest that a combined formulation of inorganic and organic agents can enhance UV protection more effectively than either type alone. One reason for the synergistic effect may be that the consolidated processes in addition to higher photon absorption contributes to higher SPF, allowing for stronger protection. While Lademann *et al*.'s study focused on UV-B spectrum, Ezekwe *et al* expanded this evaluation into the UV-A1 and visible light range. Ezekwe *et al*. found that many commercial sunscreens do not offer adequate protection against UV-A radiation and visible light. They found that the product containing iron oxides, pigments used in tinted products to block visible light, provided higher and more consistent protection in comparison to a product mixing inorganic and organic ingredients. This finding suggests that tinted inorganic sunscreens containing iron oxides, rather than untinted ones, might be a suitable choice for full-spectrum protection. Essentially, Ezekwe *et al*. finds that inorganic sunscreens are more effective in regards to visible light, which may serve as a consumer benefit when finding a practical sunscreen. One possible reason for these differences may be that Lademann *et al*. did not address or test protection beyond 400 nanometers, and visible light was not included. Overall, Lademann *et al*. and Ezekwe *et al*.'s insights support a nuanced perspective of sunscreen efficacy and further highlight the need for further clinical studies developing these findings with inclusion of visible light.

PERSISTENCE

Despite having equivalent SPF values, the persistence of sunscreen agents demonstrates mixed results during everyday activities, even when controlling for inactive formulation ingredients, which may influence consumer practicality. Rachmani *et al*. found that inorganic sunscreens provided superior persistence in terms of SPF when compared with organic sunscreens (7). This clinical trial was double-blind and randomized, studying 22 participants, aged 18-40 years, who practice swimming at least three times a week for 1.5 hours in the morning or evening (7). In this study, inorganic sunscreen was applied to one area of the participants' bodies, while organic sunscreen was applied to another area. The participants were measured for the difference in SPF 30 before and after water exposure of 1.5 hours, using a standardized SPF testing protocol. Results found that the SPF values of the inorganic sunscreens decreased less than those of organic sunscreens to a significant extent (7). Essentially, the post-water exposure SPF for the inorganic sunscreen group remained closer to the pre-water exposure baseline. Limitations of this study include solely SPF 30 being tested, short-term testing, as well as a limited sample size in terms of quantity and diversity, being that only 22 swimmers were tested.

Another study conducted by Bodekaer *et al*. offers a different perspective in that it found that inorganic and organic sunscreens lose their protection strength at the same rate. In this clinical study, 24 volunteers were tested in order to examine the durability between two sunscreen agents (inorganic and organic). Researchers applied seven squares of sunscreen on each volunteer's back; specifically, one area of the seven was phototested to determine UV sensitivity, and the other six areas were treated with either an organic or an inorganic sunscreen (specifically 2 mg of sunscreen per square cm of skin) (8). The volunteers then engaged in physical activities, were exposed to a heated environment, and bathed throughout eight hours. They were phototested with UV-B radiation 30 minutes, 4 hours and 8 hours after initial sunscreen application (8). Results found that the SPF of the inorganic sunscreen reduced by 38% and the SPF of the organic sunscreen reduced by 41% after four hours, and respectively by 55% and 58% after the full eight hours (8). Limitations of this study include a measure of SPF rather than biological skin damage, as this study did not account for UV-A damage. This limitation does not provide insight on important biological effects that may occur, as UV-A rays penetrate deeper into the skin. Additionally, there is a lack of clarity regarding the demographics of the volunteers, as there is no indication of diversity among the volunteers in terms of skin types, ages, or sun sensitivity.

Furthermore, another study, conducted by Rouabhia *et al*., aimed to test the protection of a physical sunscreen containing titanium dioxide and SPF 28. This study used engineered human skin in a lab to mimic human skin, where half of the samples were covered with the physical sunscreen, and the other half were left untreated. Both groups of samples were exposed to simulated sunlight, a lab-controlled combination of UV light. Following exposure, the samples were analyzed with histology, immunohistochemistry, and molecular tests to specifically measure DNA damage (9). Results showed that the untreated skin samples experienced major damage of the epidermis (the living layer of skin), complete loss of laminin (a crucial functional protein), and high levels of molecular DNA damage

(9). Conversely, the sunscreen prevented the other skin samples from experiencing simulated sunlight induced epidermal damage at lower UV doses, allowed for laminin accumulation, and significantly reduced molecular photodamage (9). Limitations include the age of the study, in that it may not reflect the advances in sunscreen science, technology, and formulations. Furthermore, the study only measured with a single SPF of 28, limiting the ability to generalize the results with higher or lower SPFs. This study strictly tested with an inorganic sunscreen, disallowing a direct comparison among organic sunscreens. Moreover, this study was lab-based, using stimulated samples of both skin and sunlight; it may not perfectly demonstrate the reliability of natural sun exposure.

Another study, performed by Jorge Aburto-Corona and Luis Aragón-Vargas, tested the effect that inorganic sunscreens had on sweat rates in comparison to organic sunscreens. This study used a randomized crossover design, with the participants including twenty physically active college students, specifically ten males and ten females (10). Aburto-Corona and Aragón-Vargas tested the effects of two water-resistant sunscreens, one being an inorganic sunblock and the other being an organic sun filter, specifically evaluating the sweat production in a controlled environment (30.2°C ± 0.4°C, 58% ± 4.3% relative humidity) (10). Participants had sweat-collection patches applied around their right and left shoulder blades, in which they performed two exercise sessions on consecutive days (10). The inorganic and organic skin treatments were randomly assigned to participants, and they had to pedal for twenty minutes in the heat controlled environment. The study found that the sweat rate was lower with the inorganic sunblock (99.3 $\mu L/min \cdot dm^2$) in comparison to the organic sun filter (114.8 $\mu L/min \cdot dm^2$) (10). The organic sun filter proved to be just as anti-sweat as the antiperspirant tested (control group) (10). It is important to note that this study included a limited sample size in terms of quantity and diversity, in addition to the sweat glands solely being measured in one area, failing to account for sweat rates among the whole body.

Overall, Rachmani *et al*. discovered inorganic sunscreens lasted significantly longer on the skin compared to organic sunscreens following swimming. These findings suggest that water exposure reduces sunscreen protection of both sunscreens, as both types had lost SPF effectiveness over the 1.5 hour testing period. Additionally, the results indicate that inorganic sunscreens possess better photostability and persistence in comparison to organic sunscreens, as the SPF was higher after swimming. Alternatively, Bodekaer *et al*. found no significant differences between inorganic and organic sunscreens following eight hours of physical activity, which included bathing. These findings propose that inorganic and organic sunscreens may have the same level of persistence. One plausible explanation for these differences may be that Rachmani *et al*.'s study contained swimming under controlled measures (1.5 hours), while Bodekaer *et al*.'s study seemed to be uncontrolled, as the specific time spent bathing is unindicated. These differences suggest that water exposure for less than 1.5 hours might be tolerable, but past that time the SPF may be less effective, leading to a loss in sunscreen protection and lower persistence. Additionally, these findings may influence swimmers in their optimal choice of sunscreen; if they plan to swim longer than 1.5 hours, they may choose to purchase inorganic sunscreens. Offering a different perspective, Aburto-Corona and Aragón-Vargas found that the sweat rates for inorganic sunscreens were lower than the sweat rates for organic sunscreens. This finding suggests that inorganic sunscreens may block sweat more, inhibiting the ability for the body to naturally cool itself. These results suggest that in terms of consumer viability, inorganic sunscreens may be more suitable for daily use, while organic sunscreens may be more suitable for sports or heat exposure, to maintain better thermoregulation. Complementing their findings, Rouabhia *et al*. found in a lab-controlled simulation that inorganic sunscreens prevented skin samples from experiencing photodamage, while untreated skin samples experienced major epidermal photodamage and loss of proteins. Although this study did not include organic sunscreens as a direct comparison, it still reinforces the persistence of inorganic sunscreens in terms of protection, which is information considered by consumers.

Safety

Of equal importance, the specific physicochemical properties of inorganic and organic sunscreens also contribute to their level of safety. Specifically, inorganic sunscreens are found to possibly be safer than organic ones, based on recent studies. For example, Matta *et al*. found that systemic absorption related to sunscreens is a safety concern, as ingredients absorb into the bloodstream rather than stay on the skin surface. In this randomized clinical trial, 24 healthy volunteers were split into four groups, with each group consisting of three men and three women. Each group was assigned a specific organic sunscreen: avobenzone, oxybenzone, octocrylene, or ecamsule (2). The sunscreens were applied four times daily for four days to 75% of the participants' body surface area, specifically two milligrams of sunscreen per 1 cm^2 (2). Within one day of testing, Matta *et al*. found that all four organic sunscreens were absorbed into the participants bloodstream at levels exceeding the Food and Drug Administration (FDA) threshold. It is important to mention that in this study, systemic absorption was potentially overestimated. Essentially, participants or consumers may not apply sunscreen as frequently or extensively as done in the study. This serves as a limitation as it influences universality of the results. Additionally, the study does not account for consumers who may have weaker skin barriers, as only healthy participants are included.

Additionally, a retrospective analysis conducted by Warshaw *et al*. suggests that allergic contact dermatitis (ACD) is relatively uncommon, yet more prominent with organic sunscreen use in comparison to inorganic ingredients. The study included patch testing of 23,908 participants, differentiating in gender and age, between 2001 and 2010 by the North American Contact Dermatitis Group (11). Results showed that 219 of the patients, about 0.9%, had allergic reactions to the active organic ingredients of the sunscreen. The primary ingredient causing the reaction was Benzophenone-3 (oxybenzone), which is a common organic sunscreen agent (11). It is important to note that this study was a retrospective analysis and relied on existing records, rather than obtaining more recent data. Additionally, this study does not directly compare inorganic sunscreens to organic sunscreens, yet provides insight specifically about a safety concern of organic sunscreens, which can impact efficacy.

Another clinical study, conducted by Mohammed *et al*. aimed to examine whether zinc oxide nanoparticles (ZnO-NPs) can cause toxicity by penetrating into the skin to reach living cells. The study consisted of five healthy volunteers, aged 20-30 with no active skin disease and/or damaged skin. The ZnO-NPs were formulated into an inorganic sunscreen, which was then applied to the volunteers hourly for six hours and then once daily over the span of five consecutive days (12). The study was performed *in vivo* (conducted within a living organism), where a 'multiphoton tomography with fluorescence lifetime imaging microscopy' was used to detect the ZnO-NPs among the volunteers' skins. The researchers found that the ZnO-NPs stayed among the skin surface, not penetrating into the viable epidermis (12). They also found that the imaging showed no correspondence with the particles being internalized nor toxicity in the viable epidermis (12). One factor of this study that can serve as a potential issue in terms of safety is that researchers found slightly elevated zinc ions in the skin, though the impact of this finding remains unclear (12). The primary limitations of this study include a limited sample size and short-term exposure. Furthermore, the inclusion criteria for the study included no skin diseases or damage, so this study does not address the safety aspect of ZnO-NP penetration for those with damaged skin barriers.

Similarly, an *ex vivo* study, conducted by Leite-Silva *et al*, also aimed to test how much ZnO-NPs in sunscreens can penetrate human skin, yet particularly under realistic conditions simulating impaired skin barriers. The study used 12 human skin samples derived from the abdomen, simulating intact, tape-strapped, and occluded skin (13). Two sunscreen treatments were applied to the skin samples: one with silane-coated ZnO-NPs, and the other with uncoated ZnO-NPs. The skin samples were exposed for six hours, mimicking realistic application duration. Results found that only 3-6% of the applied ZnO-NPs stayed among the stratum corneum (the outermost layer of skin), and not into the epidermis layers (13). These results suggest inorganic sunscreen ingredients are likely safe even when the skin is compromised, which proposes that inorganic sunscreens are safer for those with weaker skin barriers.

Collectively, Matta *et al*. found that organic ingredients from organic sunscreens were systemically absorbed through the skin and into the bloodstream. This finding indicates that the presence of chemicals in the bloodstream can have potential biological effects, posing a safety concern for the individual especially when used long-term. Offering a different perspective, Mohammed *et al* studied inorganic sunscreens, finding that ZnO-NPs were unlikely to penetrate into the epidermis and affect the living layers of skin/cells. While this study did not include participants with damaged skin barriers, the general consensus portrays that the ZnO-NPs tend to remain on the surface. Complementing Mohammed *et al*'s findings, Leite-Silva *et al* found that ZnO-NPs continued to have minimal to no penetration into human skin samples, even when the skin was compromised. Leite-Silva *et al*'s findings suggest that even when the skin barrier is weaker, ZnO-NPs mostly do not penetrate beyond the outermost skin layer. Mohammed *et al* and Leite-Silva *et al*'s findings collectively suggest that with inorganic sunscreens, there is little to no chance that the ingredients will penetrate into the skin due to their mechanisms, limiting chance to reach blood vessels or damaging DNA. Similarly, Warshaw *et al*. suggests that ACD is more likely to occur with organic sunscreen use. The filter detected in this study was oxybenzone, which is a common filter in organic sunscreens, raising concerns about long-term and consistent use of organic sunscreens, especially for individuals who have sensitive skin or a history of allergies. While this discussion subtly addresses safety, the limited quantity of direct comparative trials highlights a need for more rigorous studies to confirm and support these findings.

CONCLUSION

This review compared factors of inorganic and organic sunscreens in terms of persistence, safety, and overall efficacy. Both types of sunscreens demonstrate effective photoprotection despite their specific mechanisms. The results indicate that inorganic sunscreens may be a more suitable application for individuals with sensitive skin or weak skin barriers, as the ZnO-NPs contained among most inorganic sunscreen formulations are found to barely penetrate the skin. It is important to note that factors such as variations in the sunscreen formulation, consumer practicality, and testing conditions of the studies included contribute to an indefinite answer of which sunscreen formulation is more effective. Understanding the difference between inorganic and organic sunscreens is crucial for dermatologists and consumers in recommending certain sunscreens and avoiding allergic reactions or related health issues. Despite the insights gained among this review, there is a notable lack of controlled clinical trials with large sample sizes that directly compare organic and inorganic sunscreens. Future research and trials regarding this comparison should aim to measure results long-term, using human participants from various demographic, skin, and health backgrounds through standardized testing.

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CONFLICT OF INTERESTS

The author declares that there are no conflicts of interest regarding the publication of this article.

REFERENCES

1. American Academy of Dermatology Association. (n.d.). *Skin cancer statistics*. American Academy of Dermatology Association. https://www.aad.org/media/stats-skin-cancer (accessed on 2024-07-01)
2. Matta MK, Zusterzeel R, Pilli NR, Patel V, *et al*. Effect of Sunscreen Application Under Maximal Use Conditions on Plasma Concentration of Sunscreen Active Ingredients: A Randomized Clinical Trial. *JAMA*. 2019; 321 (21): 2082–2091. https://doi.org/10.1001/jama.2019.5586
3. Maier T & Korting HC. Sunscreens – Which and what for? *Skin Pharmacology and Physiology*. 2005; 18 (5): 253–262. https://doi.org/10.1159/000087606
4. Raymond-Lezman JR & Riskin SI. Sunscreen safety and efficacy for the prevention of cutaneous neoplasm. *Cureus*. 2024; 16 (3): Article e56369. https://doi.org/10.7759/cureus.56369
5. Jürgen Lademann, S. Schanzer, Ute Jacobi, H. Schaefer, F. Pflücker, H. Driller, J. Beck, M. Meinke, Andre Roggan, & Wolfram Sterry. "Synergy effects between organic and inorganic UV filters in sunscreens," *Journal of Biomedical Optics*. 2005; 10 (1): 014008. https://doi.org/10.1117/1.1854112
6. Ezekwe N, Pourang A, Lyons AB, Narla S, *et al*. Evaluation of the protection of sunscreen products against long wavelength ultraviolet A1 and visible light-induced biological effects. *Photodermatology, photoimmunology & photomedicine*. 2024; 40 (1): e12937. https://doi.org/10.1111/phpp.12937
7. Rachmani K, Yusharyahya S, Sampurna A, Ranakusuma R & Widaty S. The comparison of sun protection factor 30 persistence between inorganic and organic sunscreen in swimmers: Double-blind randomized clinical trial. *JMIR Dermatology*. 2023; 6: e41633. https://doi.org/10.2196/41633
8. Bodekaer M, Faurschou A, Philipsen PA & Wulf HC. Sun protection factor persistence during a day with physical activity and bathing. *Photodermatology, photoimmunology & photomedicine*. 2008; 24 (6): 296–300. https://doi.org/10.1111/j.1600-0781.2008.00379.x
9. Rouabhia M, Mitchell DL, Rhainds M, Claveau J & Drouin R. A physical sunscreen protects engineered human skin against artificial solar ultraviolet radiation-induced tissue and DNA damage. *Photochemical & Photobiological Sciences*. 2002; 1 (7): 471–477. https://doi.org/10.1039/b107894c

10. Aburto-Corona J & Aragón-Vargas L. Sunscreen Use and Sweat Production in Men and Women. *Journal of athletic training*. 2016; 51 (9): 696–700. https://doi.org/10.4085/1062-6050-51.11.01
11. Warshaw EM, Wang MZ, Maibach HI, Belsito DV, *et al*. Patch test reactions associated with sunscreen products and the importance of testing to an expanded series: retrospective analysis of North American Contact Dermatitis Group data, 2001 to 2010. *Dermatitis : contact, atopic, occupational, drug*. 2013; 24 (4): 176–182. https://doi.org/10.1097/DER.0b013e3182983845
12. Mohammed YH, Holmes A, Haridass IN, Sanchez WY, *et al*. Support for the Safe Use of Zinc Oxide Nanoparticle Sunscreens: Lack of Skin Penetration or Cellular Toxicity after Repeated Application in Volunteers. *The Journal of investigative dermatology*. 2019; 139 (2): 308–315. https://doi.org/10.1016/j.jid.2018.08.024
13. Leite-Silva VR, Sanchez WY, Studier H, Liu DC, *et al*. Human skin penetration and local effects of topical nano zinc oxide after occlusion and barrier impairment. *European journal of pharmaceutics and biopharmaceutics : official journal of Arbeitsgemeinschaft fur Pharmazeutische Verfahrenstechnik e.V*. 2016; *104*: 140–147. https://doi.org/10.1016/j.ejpb.2016.04.022