Original Article

Global Trends of Sunscreen Research Literature: A Bibliometric Analysis over the Period of 2010–2020

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Abstract

Objective: To date, little effort has been devoted to summarizing worldwide research trends in sunscreen publications. The present study aimed to quantitatively analyze research trends in sunscreen publications over the past period from 2010 to 2020. **Materials and Methods:** The required bibliometric information was extracted and downloaded from the Scopus database. Documents including the keywords "Sunscreen" and "Sunscreens" were extracted from the database. A total of 1466 articles were retrieved from the database as on May 14, 2021. Data analysis and visualization were performed through RStudio. The bibliometrix package was accessed through the RStudio application to compute and process the bibliotec file. **Results:** Over the last decade (2010–2020), marked progress has been made in the area of sunscreens research. The overall increase in publications and citations reflects a growing research interest in the sunscreens field. The United States was the most prolific organization productive country with (n = 861) published documents, followed by Brazil (n = 273), Australia (n = 220), and France (n = 220). The most active institution was the Universidade Federal do Rio de Janeiro with publications (n = 30). *Journal of the American Academy of Dermatology* was the leading journal in the sunscreen literature with a total of (n = 55) documents. **Conclusion:** The main strength of the study is the use of the bibliometric analysis method and visualization of data to review the entire literature on sunscreens. The United States, Brazil, the United Kingdom, Australia, France, and China were active in most of the research parameters included in the study. These findings serve as a guide and road map for scholars in the field. This research can also be beneficial to academics, policymakers, and educational use.

Keywords: Bibliometric, global, sunscreen

Introduction and Background

In the Western world, skin cancer is the most frequent malignancy. However, sunscreens are the favorably popular measures of protection against ultraviolet radiation (UVR). Sunscreens have been used since ancient civilizations, along with a variety of other practices to restrict sun exposure.[1] The sunscreen acts to prevent photodegradation of the product on the shelf, in conjunction with its protective role against the photodamaging effects of both ultraviolet B (UVB) and ultraviolet A (UVA) radiation.[2] These products have been commercially available for 70 years, but the past 30 years has seen this area develop into a multi-billion dollar industry. In 2019, the global sunscreen cream market was valued at around 8.5 billion dollars, with a projection of over 10.7 billion dollars by 2024.[3] The necessity for broad-spectrum UVA and UVB protection has prompted scientists all around the world to develop innovative cosmetic compositions and delivery techniques. New sunscreen actives, emollients, cosmetic, and functional components have been added to the formulator's arsenal on a regular basis.[4]

To date, there has been minimal effort put toward summarizing global trends in sunscreen research publications. This is the first study to use the bibliometric methodology to report and evaluate global trends in sunscreen research. A bibliometric study is a means of determining how much a research publication contributes to the advancement of knowledge. The current study

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aimed to quantitatively analyze trends in sunscreen publications over the past 10 years, including patterns of sunscreen publication, study types/designs, total citations, contributing countries/institutions, most cited countries, types of journals, keyword analysis, country collaboration, and globally most cited publications.

Materials and Methods

Design

To explore the published publications regarding sunscreen research from 2010 to 2020, a statistical and graphical bibliometric analysis was undertaken. The titles, abstracts, year of publications, study types, total citations, contributing countries, organizations, keywords, publishing journal, country collaborations, and globally most cited articles were analyzed using descriptive methods and bibliometric mapping.

Data collection

The Scopus database (Elsevier B.V.) provided a text format document that contained all the bibliometric data. Several synonyms or equivalent phrases were used to assure data accuracy and included in the search strategy. The keywords "Sunscreen" and "Sunscreens" were used along with the "title" function in the advanced search. The literature search was performed for all published articles on sunscreens from 2010 to 2020. A total of 1466 articles were retrieved when the data were extracted on May 14, 2021. These data were exported in .bib format with "full record and cited references" from the Scopus website.

Data analysis

Data analysis and visualization were performed through RStudio. RStudio is an integrated programming language for statistical computing and estimation of exhaustive data sets. The bibliometrix package was accessed through the RStudio application to compute and process the bibliotec file. This bibliometrix package is a special open-source tool specifically programmed for scientometric analysis. Infographics mapping of the scientometric networks for the study was created using "Biblioshiny," a web-based tool.

Results

Study types

Among all 1466 publications, journal articles were (n = 1034) as shown in Table 1. In other study types, there were review articles (n = 124), letters (n = 79), conference papers (n = 60), notes (n = 60), and book chapters (n = 54). Journal articles were the highest among all study types.

Metric trend of publication year and total cites

There was an increasing trend in the number of publications from the year 2015. The highest number of publications were in the year 2019 (n = 205). Mean total citation per year was the highest in the year 2014 with 3.34. From the year 2014, mean total citation per year was more than 2, except in the year 2020. Citation behavior is in direct correlation with journal impact factor [Table 2].

Contributing countries and organization

The United States was the most prolific productive country with (n = 861) published documents, followed by Brazil (n = 273), Australia (n = 220), and France (n = 220) as shown in Table 3. Among the first 10 countries, namely, China, Germany, the United Kingdom, Italy, India, and Spain also contributed more than 100 publications in the sunscreen research.

The most active institution was the Universidade Federal do Rio de Janeiro (n = 30), followed by the University of California (n = 26), the University of Sao Paulo (n = 25), the University of Warwick (n = 24), and the University of Wollongong (n = 21) as presented in Table 4.

Relevant journal impact and most cited countries

Journal of the American Academy of Dermatology was the leading source/journal in the sunscreen research literature with a total number of publications (n = 55) followed by *Photodermatology, Photoimmunology and Photomedicine* and *British Journal of Dermatology* (n = 46 and n = 41 publications, respectively). Total citations received and

Table 1: Study types published in literature

Study types	Total number of documents
Article	1034
Article in press	2
Book	1
Book chapter	54
Conference paper	60
Editorial	29
Erratum	12
Letter	79
Note	60
Review	124
Short survey	11

Table 2: Progression of annual total publications and citations

Year	Number of publications	Mean total citation per year
2020	200	1.86
2019	205	3.14
2018	147	2.83
2017	122	3.0
2016	136	2.76
2015	114	2.44
2014	95	3.34
2013	98	2.19
2012	120	1.99
2011	131	3.20
2010	98	2.39

Table 3: Contributing country/region

Country/Region	Frequency
United States	861
Brazil	273
Australia	220
France	220
China	211
Germany	188
United Kingdom	176
Italy	130
India	116
Spain	110

Table 4: Contributing organization/institution

Affiliations	Number of publications
Universidade Federal do Rio de Janeiro	30
University of California	26
University of Sao Paulo	25
University of Warwick	24
University of Wollongong	21
The University of Queensland	16
Center for Drug Evaluation and Research	15
Henry Ford Hospital	15
QIMR Berghofer Medical Research Institute	15
South China University of Technology	14

h index by these journals are described in Table 5. The above-mentioned journals are the most reputed in the field of dermatology.

The documents published by the United States were the most cited, with total citations of 5187 with average article citation 16.78%, followed by Australia (n = 2072, 35.11%), China (n = 1448, 17.87%), the United Kingdom (n = 1271, 16.94%), and France (n = 1247, 21.5%) as shown in Table 6.

In the study, most relevant corresponding authors' addresses, the United States is the leader in sunscreen research with (n = 309) publications, followed by Brazil, China, the United Kingdom, and Germany [Table 7]. Possible explanations for this are included in the Discussion section.

Most global cited documents and relevant countries by corresponding author

Table 8 highlights the most cited documents in the sunscreen research. Out of 10 articles, the most highly cited articles have been published in years 2010 and 2011. The most cited work entitled "Reduced melanoma after regular sunscreen use: randomized trial follow-up" by Green AC *et al.* published in 2011 with 472 citations. It was followed by another publication entitled "Titanium dioxide and zinc oxide nanoparticles in sunscreens: focus on their safety and effectiveness" by Smijs TG *et al.* published in 2011 that received 424 citations. "Zinc oxide nanoparticles in modern sunscreens: an analysis of potential exposure and hazard" by Osmond MJ *et al.* was another publication published in 2010 with 269 citations.

Table 5: Relevant source/journal impact in the literature

Source	h_ index	Total citations	Number of publications	Publication year
Journal of the American Academy of Dermatology	17	1115	55	2010
Photodermatology, Photoimmunology and Photomedicine	13	789	46	2010
British Journal of Dermatology	13	625	41	2010
International Journal of Cosmetic Science	12	530	40	2010
Photochemical and Photobiological Sciences	10	289	22	2010
Journal of Photochemistry and Photobiology	9	177	20	2012
Journal of Cosmetic Dermatology	6	136	19	2010
Journal of Cosmetic Science	3	32	18	2010
JAMA Dermatology	9	198	17	2013
International Journal of Pharmaceutics	9	292	15	2011

Table 6: Most cited countries

Country	Total citations	Average article citations
United States	5187	16.786
Australia	2072	35.119
China	1448	17.877
United Kingdom	1271	16.947
France	1247	21.5
Germany	913	12.681
Spain	868	19.727
Brazil	839	8.74
Italy	678	13.038
The Netherlands	668	55.667

Table 7: Most relevant countries by corresponding author

Country	Articles
United States	309
Brazil	96
China	81
United Kingdom	75
Germany	72
India	61
Australia	59
France	58
Italy	52
Spain	44

Keyword and country collaboration analysis

In detailed bibliometric keyword network analysis, it was noted that the most used keywords in this field were "*Sunscreen*," "*Sunscreening agents*," "*human*," and "*article*." The most centric key word was *Sunscreen*, with occurrences of (n = 1348) [Figure 1].

Country collaborations (co-authorship)

Publications co-authored by many countries were excluded, and the maximum number of countries per publication was set at 15. The minimum number of publications per country was fixed at five. Considering weights based on documents, the United States was the leading country with documents (n = 115) and total link strength (TLS) (n = 20 countries), followed by Germany (documents = 80, TLS = 18 countries), France (documents = 61, TLS = 17 countries), Australia (documents = 45, TLS = 17), and the United Kingdom (documents = 37, TLS = 19 countries). Co-authorship country visualization network map is presented in Figure 2.

Discussion

Over the past decade (2010–2020), a progressive advancement has been made in the area of sunscreen research. This is evident by the growth in the number of publications, their citations, and their progress in the field. Sunscreens have become the prevailing methods of UVR protection in the Western countries for more than 40 years. In the prevention of basal cell carcinoma and melanoma, the benefit of sunscreen use is yet to make mark. Large molecular last generation UVB–UVA broad-spectrum sunscreens have a better benefit–risk ratio. They offer better protection in the UVA band, and they are nontoxic and nonallergenic.[5] Among the prolific countries, the United States, Brazil, Australia, France, and China were considered very active in terms of publications in the area of sunscreen research. It is

Table 8: Most global cited documents

Authors	Journal name/year	DOI	Total citations	TC per year
Green AC, *et al.*	*J Clin Oncol*/2011,	10.1200/JCO.2010.28.7078	472	42.90
Smijs TG, *et al.*	*Nanotechnology Sci Appl*/2011,	10.2147/nsa.s19419	424	38.54
Osmond MJ, *et al.*	*Nanotoxicology*/2010	10.3109/17435390903502028	269	22.41
Krause M, *et al.*	*Int J Androl*/2012	10.1111/j.1365-2605.2012.01280.x	243	24.3
Monteiro-Riviere NA, *et al.*	*Toxicol Sci*/2011	10.1093/toxsci/kfr148	241	21.90
Gondikas AP, *et al.*	*Environ Sci Technol*/2014	10.1021/es405596y	232	29
Kim S, *et al.*	*Environ Int*/2014	10.1016/j.envint.2014.05.015	230	28.75
Gulson B, *et al.*	*Toxicol Sci*/2010	10.1093/toxsci/kfq243	222	18.5
Sadrieh N, *et al.*	*Toxicol Sci*/2010	10.1093/toxsci/kfq041	217	18.08
Balskus EP, *et al.*	*Science*/2010	10.1126/science.1193637	209	17.41

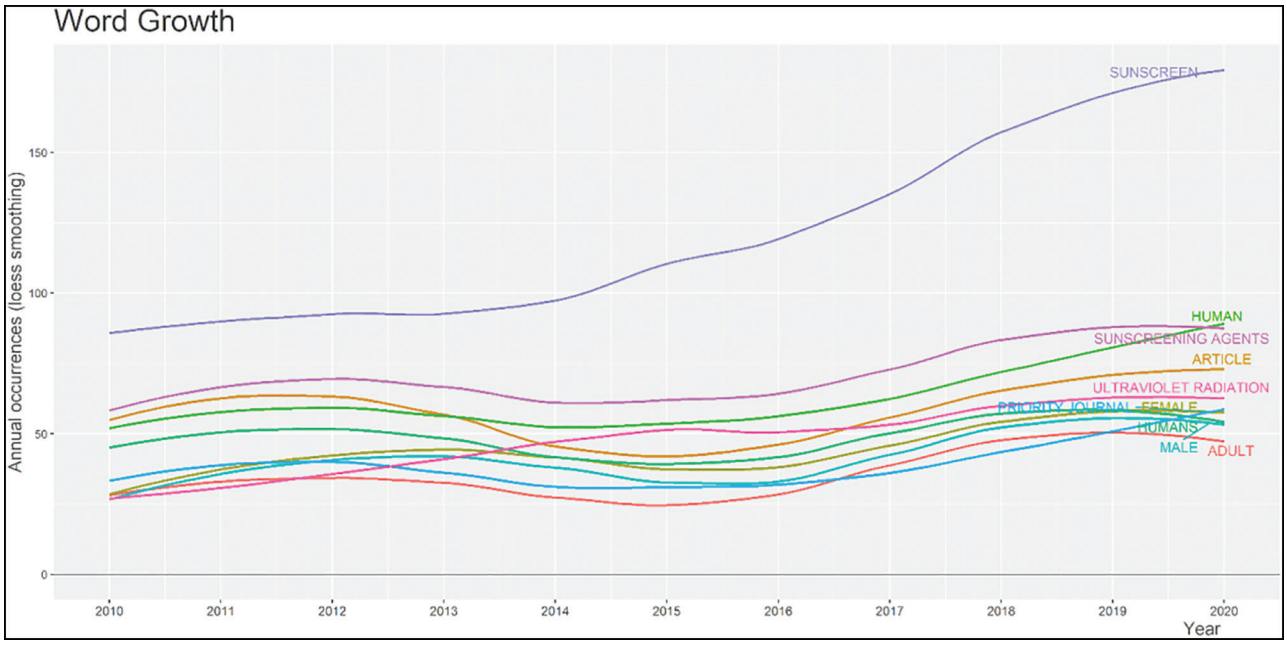

Figure 1: Keyword network analysis

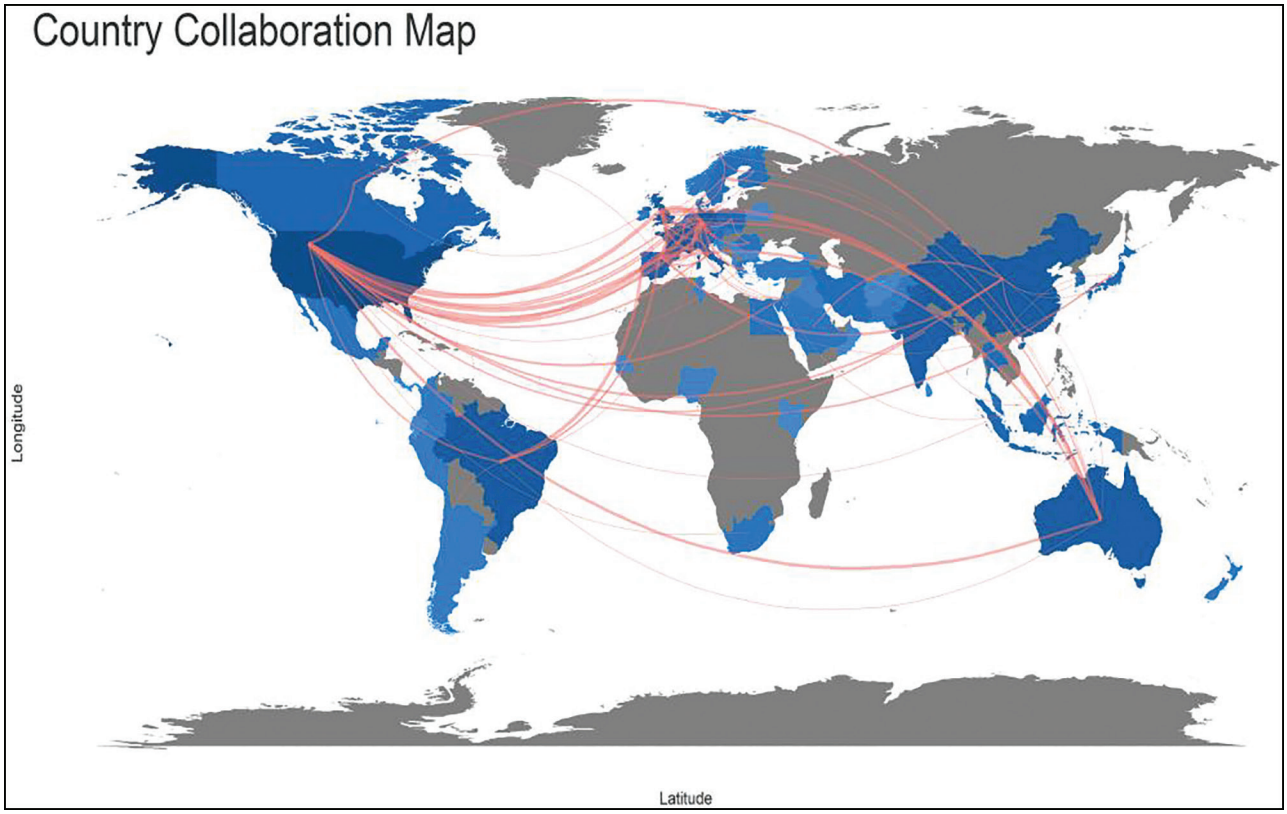

Figure 2: Country collaborations (co-authorship) visualization network

possible that this research activity is due to the huge market size and use of sunscreens in these countries. This encourages scientists to debate the real problems evolving from the society in their research activities. Incidence rates of nonmelanoma skin cancer and melanoma have been on the rise in the United States for the past 25 years. UVR exposure remains the most preventable environmental risk factor for these cancers. Aside from sun avoidance, sunscreens continue to provide the best alternative protection. Antioxidants, photolyases, and plant polyphenols remain an interesting avenue of research as additives to sunscreens or stand-alone topical or oral products that appear to modulate the immunosuppressive effects of UVR on the skin.[6] UVR protection requirements were included into a number of comprehensive legislative legislation in Australia, which established requirements for a wide range of sun protective products, including sunscreens, photoprotective clothing, sunglasses, and occupational sun exposure standards. After realizing that the magnitude of sun exposure during childhood is a major risk factor in the development of skin cancer, Australia provides successful strategies to monitor and reduce the frequency of skin cancer.[7] Melanoma prevention programs have been in place in France for over 20 years now. The time has therefore come to assess the efficacy of previous initiatives so as to define the target of future projects.[8] As per literature, a study was conducted in Chinese population to analyze demographic differences in sun protection beliefs and behavior. The research concluded that the use of sun protection is less among surveyed Chinese population, especially in males and lower socioeconomic population, which could allow for planning prevention campaigns and exploring sun-preventive products. The attitudes toward sun exposure varied greatly, showing significant differences based on gender, age, socioeconomic groups, and skin-type groups[9] Moreover as per the published literature, many of the studies related to efficacy, mechanism of action, and sun protection factor (SPF) are not yet established. Many of the studies conducted during the previous two decades have focused on protection from UVA radiation, which penetrates the skin. However, some questions need to be addressed related to progress in the last two decades. Evidently, much remains to be done on three fronts: first and foremost are (a) the safety issues of sunscreen ingredients; (b) the photostability of sunscreens, especially the photostability of the UVA filters remains an important issue, and (c) the direct cause–effect relationship between sunscreen usage and skin cancers remains to be demonstrated unambiguously.[10] Furthermore, despite the immediate and apparent consumer need for sunscreen products that deliver broad-spectrum UVB and UVA photoprotection, there is no singular method for one, agreed-upon approach for evaluating UVA efficacy. There is an urgent need for more research in the causation of melanoma and prospective clinical studies of preventive approaches including the use of sunscreens. Although

continued investigations will certainly be fruitful, existing *in vivo* animal and human studies are remarkably consistent in their conclusion that sunscreens are both safe and effective.[11] Literature research also indicates that unfortunately it is often not understood how sunscreens work, its mode of action and confusing aspect of SPF. The SPF race will soon come to an end. In the future, SPF should be given less emphasis in selecting sunscreens. Instead, the profile/quality of protection over the whole UVB/UVAII/UVAI range should be the selection criterion. The ideal sunscreen provides uniform UVB/UVA protection because this assures that the natural sun spectrum is attenuated without altering its quality. The evolving UVA assessment methods and the corresponding UVA standards are crucial in providing good ultraviolet (UV) protection to the public. The value of the SPF claimed on the label is diminished by environmental factors that are not taken into account during SPF measurements in the laboratory, such as sweating, water immersion, rubbing off, and photodegradation. There are some misunderstandings and confusions about the mode of action of physical sunscreens. It was originally considered that, in contrast to organic sunscreens, the inorganic metal oxides (zinc oxide and titanium dioxide) acted as scatterers or reflectors of UV light, as a mirror.[12,13] Another literature indicates that the use of sunscreens seemed to prove to be more and more important and popular within the last decades. However, there is still inconsistency about the usefulness of sunscreens. Several studies show that inadequate use and incomplete UV spectrum efficacy may compromise protection more than previously expected. Numerous products crowd the sunscreen market. Inorganic sunscreens such as zinc oxide and titanium oxide have a wide spectral range of activity compared to most of the organic sunscreen products. It is not uncommon for organic sunscreens to cause photocontact allergy, but their cosmetic acceptability is still superior to the one given by inorganic sunscreens. Recently, modern galenic approaches such as micronization and encapsulation allow the development of high-quality inorganic sunscreens,[14] and their safety and efficacy are still in question. Affordability and proper application techniques are the challenges that must be addressed in order to achieve regular sunscreen usage. The authors recommend further comparative studies on sunscreens as well as studies on the Indian population, as there are insufficient data in this population.[15] Nanoparticles and environmental issues are likely to be the focus of future sunscreen disputes. Owing to the possible toxicity of UV filters for individuals and the environment, sunscreen management must strike a balance between their protective effect against erythema, photocarcinogenesis, and photoaging. Sunscreens claim to protect not just from erythema but also from photoaging, precancerous lesions, and skin cancer, so we have high expectations for their performance and safety.[16] As a result of technological breakthroughs, many new UV filters have recently been developed. These have improved the treatment's efficacy and safety. Other emerging technologies may improve efficacy, such as a nonabsorbing substance to increase SPF, coating/modifications of inorganic sunscreen, stabilizing avobenzone by photostabilizers, and encapsulation of UV absorbers; microfine organic particles also may improve efficacy and safety of sun protective products.[17] However, there has been little research done on the cost of sunscreen use. The price of sunscreen grew with SPF; using a generic sunscreen resulted in savings of 40% to 50%.[18] This research can aid in the discussion of sunscreen research's future growth and in directing researchers in this rapidly evolving subject. The limitations of our article were that there was no study to compare our results within the literature and only one database was used for the study.

Conclusion

The study's key strength is its use of the bibliometric analysis method and data visualization to review the complete sunscreen literature of last 10 years. An important result of this study is that it provides a big picture overview of sunscreen's research publications. The United States was the leading country in all research parameters included in the study, followed by Brazil, the United Kingdom, Australia, France, and China. These findings serve as a guide and road map for scholars in the field. This research can also be beneficial to academics, policymakers, and educational use.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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