





ORIGINAL ARTICLE

Can crowdsourced data help to optimize atopic dermatitis treatment? Comparing web search data and environmental data in Germany

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Abstract

Background Atopic dermatitis (AD) is one of the most common chronic skin diseases worldwide, showing various manifestations and having a severe impact on quality of life. As previous studies demonstrated, internet search analysis can help identify public interest in diseases and possible influencing factors on search behavior.

Objective To identify AD-related topics of interest in Germany using internet search volume.

Methods Google Ads Keyword Planner was used to identify AD-related search terms including their search volume in Germany on a national level as well as in 16 selected cities from January 2016 to December 2019. Identified keywords were qualitatively analyzed, and temporal trends as well as the influence of seasonal and environmental factors on search volume were assessed.

Results Overall, 1222 AD-related search terms with a search volume of 8 842 360 searches were identified. An increase from 2016 to 2019 and seasonal peaks from January to April of each year were observed. Nationwide, the search volume correlated with mean monthly temperature and sun duration. With increasing temperature and sun duration, a significant decrease in search queries was observed. The most populated cities showed the lowest number of searches per 100 000 inhabitants (Berlin, Hamburg, and Munich). In the eight categories formed (comorbidities, general, influential factors, localization, stage of life, symptoms/severity, therapy/information, and questions on AD), the highest proportion of search queries were assigned to the category “therapy/information” in most cities. In this category, a focus on the topics of “alternative medicine” and “home remedies” could be observed.

Conclusion The overall high and increasing search volume indicates a high interest in AD-related topics, especially regarding treatment and disease education. Information provided by internet search volume analyses can optimize AD therapy and patient-centered care by providing insight into patient needs and predicting potential climatic trigger factors.

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Conflict of interest

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Introduction

Atopic dermatitis (AD) is a chronic recurrent inflammatory skin disease that is characterized by pruritic skin lesions and eczematous and dry skin.¹ With a worldwide prevalence of around 20% in children and 1%–3% in adults, AD is one of the most common chronic skin disorders.² The incidence of AD increased two- to threefold in industrialized nations over the last decades.^{2,3} The exact pathogenesis of AD is still not completely understood, as AD is caused by a complex interaction of

different factors. Defects in skin barrier function, immune dysregulation, and infectious and environmental factors are discussed to play a role in disease development in addition to individual triggers.⁴

AD usually has its onset in early childhood. In the majority of affected children, the disease will reach clinical remission before adulthood.⁵ However, a persistence of this disease or a late onset is possible and will not only cause continuous clinical symptoms, but also have a severe impact on the patients' and their families'

quality of life.⁶ An increased occurrence of depression, anxiety, and attention-deficit hyperactivity disorder (ADHD) in people with AD are only a few examples that underline the immense psychosocial burden of AD.⁷ According to the Global Burden of Disease Study, dermatitis (atopic, contact dermatitis, and seborrheic dermatitis) was the skin condition with the greatest negative effect on disability-adjusted life years (DALY).⁸ In addition to allergic comorbidities, AD is associated with an increased risk for infectious, metabolic, and neuropsychiatric diseases.⁹ It is therefore possible to consider AD as a systemic disorder and not just as a disease limited to the skin.^{9,10} Developing successful treatment plans can be challenging for physicians when considering the individual manifestations, multiple comorbidities, and complex systemic nature of AD. Current treatment guidelines recommend a step-care approach for the skin manifestations but no specific therapeutic plans.¹¹ The combination of the high prevalence of AD, its individual manifestations, and its significant impact on quality of life makes a population-based web search analysis a promising method to learn more about the needs and special interests of people with AD. Previous studies showed contradicting results regarding the influence of environmental parameters on the symptom severity of AD.^{12–15} For example, some studies have shown that higher outside temperatures lead to poorly controlled eczema,^{14,15} whereas other studies reached opposite conclusions.¹² Internet search data can thereby provide further insight into the role of climate on disease severity by assessing seasonal differences in search volume.

Since the internet is commonly used as a source of health information, an analysis of search behavior provides a representative overview of people's needs, including those of individuals not undergoing medical treatment.^{16,17} In Germany, 90% of the population uses the internet, and approximately 57% used the internet at least once in 12 months as a source for health-related information.¹⁸ Previous studies have shown that web search analyses can help to predict medically relevant seasons or to identify unmet needs of patients. For example, web searches correlated with the pollen season or the occurrence of certain infectious diseases.^{19–21} Thus, the aim of this study was to analyze AD-related online search behavior in Germany as a whole and in 16 German cities, focusing on seasonal trends, meteorological influences, and geographic differences to identify on a population-based level potential environmental trigger factors and unmet needs to optimize treatment options and allocation of healthcare resources.

Material and methods

Study design

In this retrospective longitudinal study, Google Ads Keyword Planner was used to assess the web search volume and search behavior related to AD in Germany between January 2016 and December 2019. Google Ads is typically used for online marketing campaigns. However, since it provides the absolute search

volume for any keyword over time, the tool can also be used for scientific inquiries.²² The German lay word for AD (“Neurodermitis”, “Atopische Dermatitis”) and the term “atopic eczema” (“Atopisches Ekzem”) were chosen for this analysis. The tool provides a list of all search terms relevant to the topic and displays the respective monthly search volume of each term. The search volume was examined for the whole of Germany and for 16 German cities (Berlin, Cologne, Dortmund, Dresden, Frankfurt, Freiburg, Hamburg, Hannover, Kiel, Leipzig, Magdeburg, Munich, Nuremberg, Rostock, Saarbrücken, and Stuttgart). These cities were selected based on population and geographical location in Germany to provide a representative nationwide overview (Fig. 1). Furthermore, differences between Northern (Hamburg, Hannover, Kiel, and Rostock), Eastern (Berlin, Dresden, Leipzig, and Magdeburg), Southern (Freiburg, Munich, Nuremberg, and Stuttgart), and Western (Dortmund, Frankfurt, Cologne, and Saarbrücken) Germany were assessed. To assess seasonal variations, the months were assigned to the seasons of spring (March, April, May) summer (June, July, August), fall (September, October, November), and winter (December, January, February). Only search queries with the language preference set as German were considered in this analysis. Since no personal data were collected,

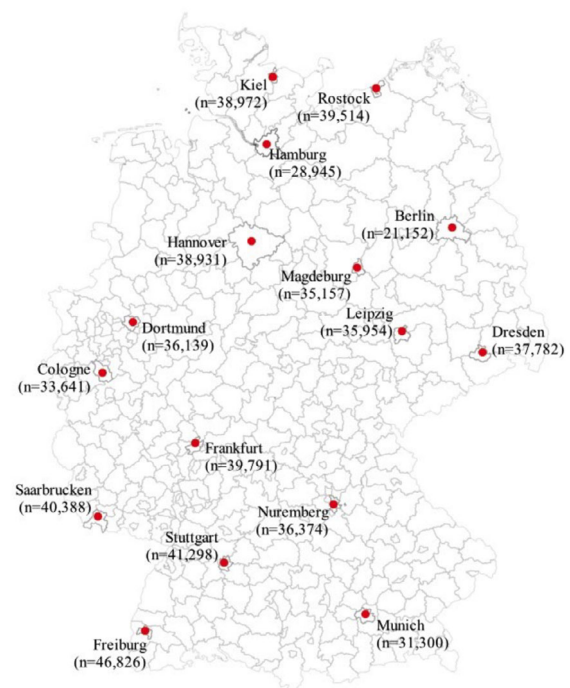


Figure 1 Google search volume per 100 000 inhabitants for AD-related keywords in 16 selected German cities from January 2016 to December 2019.

institutional review board approval was not required according to local regulations.

Statistical analysis

All identified keywords were qualitatively investigated and divided into relevant and irrelevant search terms. Irrelevant search terms (e.g. atopic dermatitis dog) and search queries that did not explicitly mention AD (e.g. pruritus baby) were excluded from further analysis. All relevant search terms were classified into eight categories: (i) “comorbidities” (e.g. allergies), (ii) “general” (e.g. atopic dermatitis), (iii) “influential factors” (e.g. atopic dermatitis stress), (iv) “localization” (e.g. atopic dermatitis face), (v) “stage of life” (e.g. atopic dermatitis baby), (vi) “symptoms/severity” (e.g. atopic dermatitis pruritus), (vii) “therapy/information” (e.g. atopic dermatitis therapy), and (viii) “questions on AD” (e.g. do I suffer from atopic dermatitis). When necessary, the terms of some categories were further divided into subcategories for a more detailed insight into the topics of interest. Search terms matching several criteria were assigned to several categories. To assess differences between the cities, the search volume was calculated per 100 000 inhabitants.²³

Sociodemographic variables (median income, inhabitants per physician, proportion of women, and average age) were obtained from the Federal Institute for Research on Building, Urban Affairs, and Spatial Development to investigate possible correlations with search volume.²⁴ Furthermore, different environmental data from the German National Climate Data Center (i.e. mean monthly temperature in °C, mean humidity in %, mean monthly sunshine duration in hours, and monthly precipitation in mm)²⁵ and atmospheric particulate matter data for particulates with a diameter of 10 µm or less (PM10)²⁶ were retrieved and used to evaluate a possible association with search volume. IBM SPSS Statistics 27 was used to determine if there was a significant effect ($P < 0.05$) of each environmental factor on search queries using linear regression models. Standardized regression coefficients (beta) and 95% confidence intervals (CIs) were calculated.

Results

A total of 1276 keywords were identified for the study time period. Of these, 54 were identified as irrelevant and excluded from analysis. The remaining 1222 relevant keywords showed a total search volume of 8 842 360 searches from January 2016 to December 2019. In Germany as a whole, the category “general” had the highest search volume with 5 051 800 (55.2%) search queries, followed by “localization” (1 344 760, 14.7%) and “therapy/information” (1 280 090, 13.9%). Overall, 638 keywords (43.9%) were classified into the category “therapy/information,” making it the category with the highest number of keywords (Fig. 2). The most common search terms were the German lay word for atopic dermatitis (“Neurodermitis”

($n = 4\,350\,500$) and atopic dermatitis baby (“Neurodermitis baby”) ($n = 314\,400$) followed by “atopic eczema” ($n = 272\,100$).

In the category “localization,” most searches were related to the face (31.8%) followed by hands (19.0%) and the genital/anal area (5.3%). In the category “symptoms/severity,” 18.0% of the searches related to itch. In the category “influential factors,” the majority of searches (36.3%) were assigned to the subcategory “stress,” and the second most common influential factor was “winter/cold”: (21.2%). In the category “therapy/information,” the subcategory “skin care” had the largest proportion of searches with 29.3%. The two subcategories “home remedies” and “alternative medicine” were responsible for 19.9% of the searches in the category “therapy/information” (Table 1).

Time course and seasonal variation of web searches

During the study period, an average of 222 searches per 100 000 inhabitants per month were conducted throughout Germany. Nationwide, an increase in searches was observed from January 2016 to December 2019. While there was an average of 148 257.5 searches per month in 2016, an increase in monthly average search queries to 239 982.5 was observed in 2019. September 2016 represented the month with the lowest search volume (140 searches/100 000 inhabitants), whereas November 2019 had the highest search volume (355 searches/100 000 inhabitants). Throughout the study period, a clear seasonal fluctuation in search volume was seen. There was a considerable increase in search queries from January to April before the search volume decreased from July to September (Fig. 3). However, the difference in search volume between the four seasons was not significant ($P = 0.057$).

Comparable to the whole of Germany, all regions showed seasonal fluctuations in search frequency with an increase in searches during the winter months. Southern Germany had the most searches per month on average (748.8 searches/100.000 inhabitants), which was significantly higher than the search volume in Northern (704.3 searches/100 000 inhabitants, $P = 0.041$) and Eastern Germany (621.7 searches/100 000 inhabitants, $P < 0.001$, Fig. 4).

Comparisons between cities

Freiburg had the highest search volume per 100 000 inhabitants ($n = 46\,826$) followed by Stuttgart ($n = 41\,298$) and Saarbrücken ($n = 40\,388$). In the five most populous cities (Berlin, Hamburg, Munich, Cologne, and Frankfurt), the category “general” had the highest search volume, while in all other cities the therapy/information’ category had the highest. In all 16 cities, the categories “questions on AD” and “comorbidities” were the categories with the fewest search queries per 100 000 inhabitants. The proportion of searches regarding “localization” varied widely among the cities, from 15.4% in Berlin to 22.3% in Saarbrücken (Table 2). In this study, no significant correlations

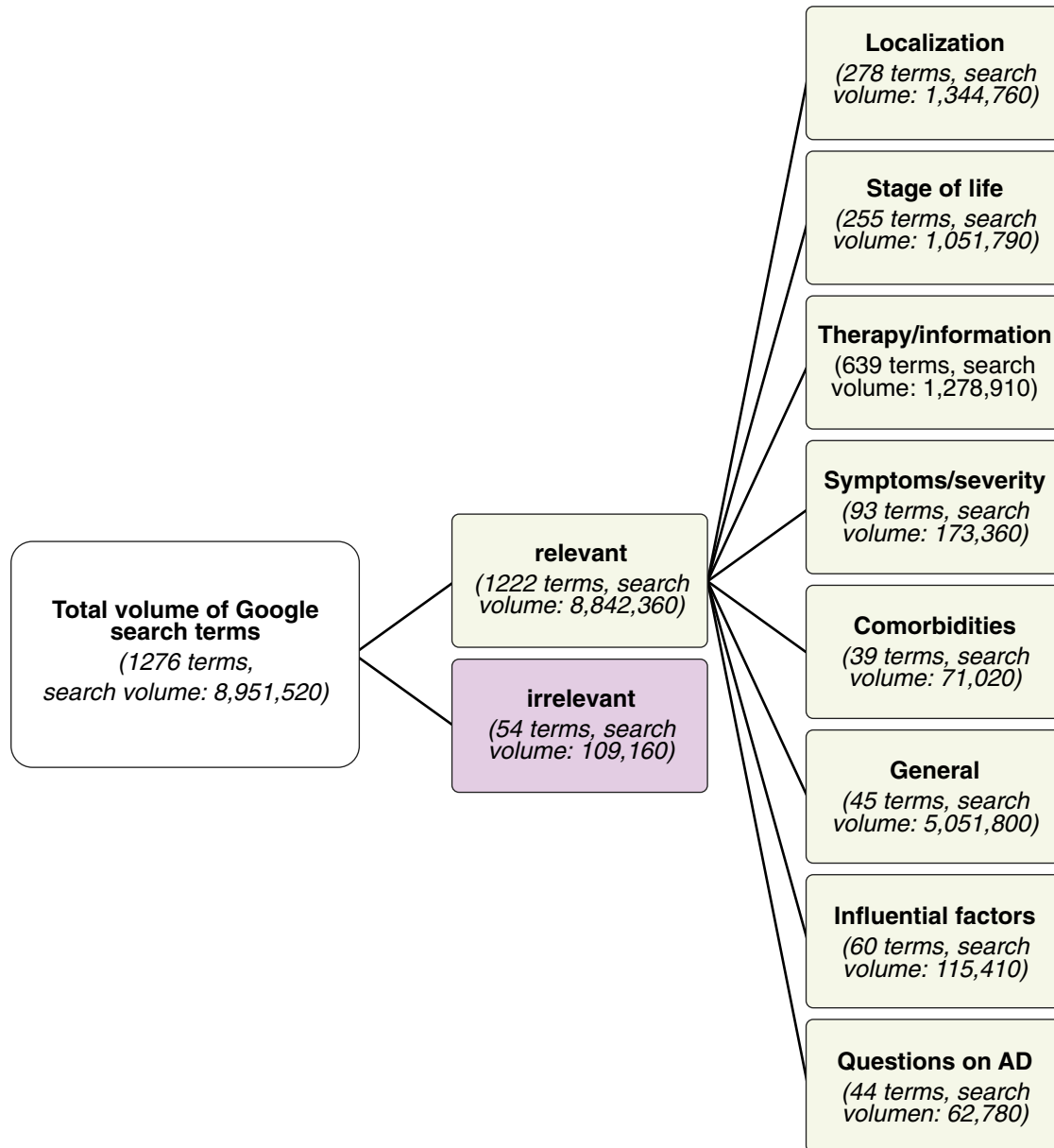


Figure 2 Content categorization of AD-related search terms.

between search volume and sociodemographic variables (median income, proportion of women in the population, residents per physician, and median age) were found.

Climate

Considering the whole of Germany, the mean monthly temperature (beta -8.136 , 95% CI $[-9.791; -6.482]$, $P < 0.001$) and the monthly sun duration (beta -0.345 , 95% CI $[-0.485; -0.206]$, $P < 0.001$) had a significant negative influence on the

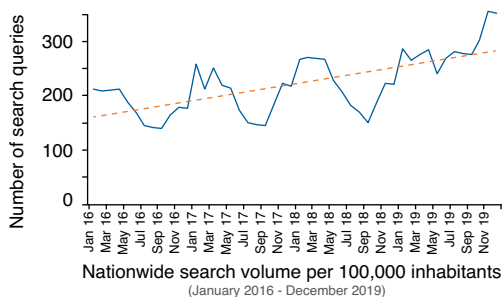
search volume. For all other environmental factors investigated, no significant association with the number of searches were found (Table 3).

Discussion

The study aimed to analyze the AD-related web search behavior in Germany as a whole and 16 German cities, focusing on seasonal trends, geographic differences, and meteorological influences to identify on a population-based level potential

Table 1 Nationwide Google search volume of selected categories and the percentage of their five largest subcategories

Category	Search queries nationwide in total	Top 5 subcategories (search volume)				
Localization	1 344 760	Face 31.8%	Hand 19.0%	Eyes 16.5%	Head 12.0%	Genital/Anal area 5.3%
Stage of life	1 051 790	Baby 60.4%	Child 27.9%	Adults 6.2%	Pregnancy 3.3%	Older age 2.1%
Therapy/Information	1 278 910	Skin care 29.3%	Therapy 17.3%	Skin care Brand name 15.1%	Alternative medicine 10.5%	Home remedies 9.4%
Symptoms/Severity	173 360	Pruritus 18.0%	Light (severity) 16.8%	Blisters 14.6%	Skin rash 10.2%	Dry skin 9.2%
Comorbidities	71 020	Psoriasis 34.1%	Allergy 25.3%	Hair loss 17.4%	Acne 9.8%	Sun allergy 5.6%
Influential factors	115 410	Stress 35.9%	Winter/cold 21.9%	Psyche 10.0%	Bowel 9.9%	Sugar 8.3%

**Figure 3** Nationwide search volume per 100 000 inhabitants per month from January 2016 to December 2019.

environmental triggers and unmet needs to optimize AD treatment and allocation of healthcare resources. From January 2016 to December 2019, a total of 8 842 360 searches were made, with increasing numbers during the study period. The most frequently searched terms belonged to the “general” category. In most cities, however, the category “therapy” had the highest search volume.

AD therapy includes a basic therapy in the form of careful skin care and cleansing, which should help to strengthen the skin barrier and prevent irritation.²⁷ The therapeutic options for symptom exacerbation have long been limited to topical corticosteroids, calcineurin inhibitors, and systemic immunosuppressants. The so-called corticoid phobia describes concerns of patients and physicians related to corticosteroid therapy and is one of the main reasons why some patients with AD are undertreated or show therapy non-compliance.^{28,29} Despite the growing availability of targeted therapies as a result of the better understanding of AD pathogenesis, the high searches for “therapy” suggest a possible dissatisfaction with current therapies or a need for information about alternative treatment options. Interestingly, 19.9% of the keywords in the category

“therapy/information” referred to alternative medicine and home remedies. Previous studies demonstrated that about half of patients with AD use alternative treatment options.³⁰ There appears to be a high demand for alternative treatment despite the few studies on this topic.³¹ Further studies on the effectiveness of alternative treatments are needed to address this unmet public interest.

The most affected body parts in adults are the popliteal fossae, lower legs, dorsal feet, and antecubital fossae.³² In contrast, most searches in this study related to the “face” or “hands.” Chronic skin diseases such as AD can lead to stigmatization of affected individuals.³³ Patients with AD can experience criticism for scratching their skin or be bullied because of their skin lesions. The false belief that AD skin lesions are potentially contagious can also lead to social exclusion of affected individuals.³⁴ One conceivable reason for the high search volume for the “face” and “hands” in this study is the immediate visibility of skin lesions in these areas to other people and the difficulty in covering them. Another possible reason for the high amount of search queries for the “hands” is the functional impairment in everyday and professional life due to hand eczema. For instance, fifteen percent of patients with chronic hand eczema report being excluded from the job market and 8% of patients have to change their job because of it.³⁵ Even if these localizations do not correspond with the objectively most frequent ones, it is possible that they are perceived to be the most burdensome lesions because of stigmatization and functional impairment. Similar conclusions can be made for the symptom “itch,” which had the highest search volume for symptoms in this study. In a study analyzing Google search queries regarding itch, most queries related to AD.³⁶ Another study showed that more Google searches focus on chronic itch instead of acute itch.³⁷ Based on this high search volume, the symptom “itch” can be interpreted as being particularly burdensome for individuals with AD. Additionally, stress was the most searched influencing factor. These observations provide further evidence for the relationship between AD and

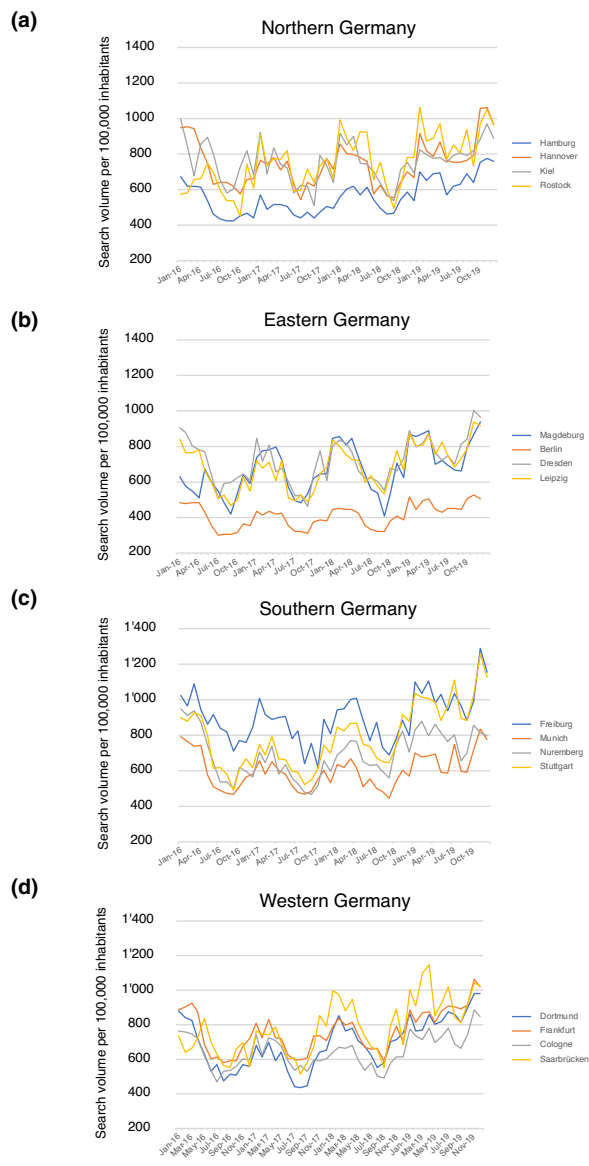


Figure 4 Google search volume per 100 000 inhabitants per month for AD-related keywords in 16 German cities from January 2016 to December 2019. (a) Google search volume per 100 000 inhabitants for AD-related keywords in Northern Germany. (b) Google search volume per 100 000 inhabitants for AD-related keywords in Eastern Germany. (c) Google search volume per 100 000 inhabitants for AD-related keywords in Southern Germany. (d) Google search volume per 100 000 inhabitants for AD-related keywords in Western Germany.

stress. On one hand, stress can lead to an aggravation of AD symptoms. On the other hand, the psychological burden of AD itself leads to further stress for affected individuals.³⁸ As patient education programs have shown to be a beneficial element of

AD treatment,³⁹ educating patients in this context about the interplay between stress and symptoms may better equip them with effective stress coping strategies as an efficient part of the treatment of patients with AD.⁴⁰ In this context, it might be useful to better educate patients about the interplay between stress and AD and to develop methods for coping with stress.

It was observed that smaller cities with fewer inhabitants had a higher search volume per 100 000 inhabitants than larger cities. Freiburg showed the highest relative search volume, while Berlin showed the lowest. These results were comparable to those of a previous study, which examined the Google search behavior for pruritus in German cities.³⁷ The authors concluded that the lower mean age and higher proportion of women in Freiburg are two possible explanations for its relatively higher search volume.³⁷ It should be noted that non-German language search queries were not considered in this study, meaning that cities with a higher percentage of individuals who do not speak German may also be responsible for the geographic differences in search volume.

Studies previously demonstrated that climatic factors can influence the symptom severity of AD, but these results do not coincide with our findings. A majority of these studies concluded that high temperature, increased sun exposure, and higher humidity levels can aggravate AD symptoms.^{14,41} Other studies concluded that low temperatures can lead to poorly controlled eczema.^{12,42} Our findings show, however, a considerable increase in search volume during the winter months in all cities, suggesting that high temperatures are not solely responsible for symptom exacerbation. Additionally, queries about “winter/cold” in the category “influential factors” had the second highest search volume. UV light therapy, which is often used in AD treatment and is based on the immunosuppressive effect of UV light, supports the theory that UV light exposure can improve AD symptoms. Overall, these observations suggest that an interplay of temperature and humidity, for example, by increased sweating during the summer, may play a greater role in AD symptom development than temperature alone.

Identifying seasonal trends using online search query analyses, which have been conducted for other diseases like influenza,⁴³ can help optimize treatment plans. Our findings, for example, suggest higher or unmet needs of individuals affected with AD during the winter months. Treatment plans can therefore be adjusted according to seasonal changes in disease manifestations to minimize symptom exacerbation, such as by adapting baseline skin care based on weather forecasts. However, AD is a complex multifactorial disease, and this thesis would need to be evaluated in future studies.

Limitations

There are a few study limitations. Web search analyses only include data from people who have access to the internet, and this study only analyzed the search volume of one single search

Table 2 Google search volume per 100 000 inhabitants in 16 German cities, each in total and per category

City (overall search volume)	Inhabitants 2019	Categories and searches per 100 000 inhabitants								Total
		Comorbidities (39 keywords)	General (45 keywords)	Influential factors (59 keywords)	Localization (278 keywords)	Stage of life (256 keywords)	Symptoms/severity (93 keywords)	Therapy/information (639 keywords)	Questions on AD (44 keywords)	
Berlin (722 410)	3 669 491	314 (1.5%)	8097 (38.3%)	464 (2.2%)	3246 (15.4%)	2744 (13.0%)	776 (3.7%)	5181 (24.5%)	329 (1.6%)	21 152
Hamburg (496 140)	1 847 253	508 (1.8%)	9681 (33.5%)	757 (2.6%)	5112 (17.7%)	3533 (12.2%)	1200 (4.2%)	7623 (26.3%)	529 (1.8%)	28 945
Munich (428 630)	1 484 226	564 (1.8%)	10 240 (32.7%)	820 (2.6%)	5344 (17.1%)	4107 (13.1%)	1243 (4.0%)	8425 (26.9%)	557 (1.8%)	31 300
Cologne (338 820)	1 087 36	662 (2.0%)	10 575 (31.4%)	902 (2.7%)	6103 (18.1%)	4111 (12.2%)	1415 (4.2%)	9247 (27.5%)	627 (1.9%)	33 641
Frankfurt (280 320)	763 380	774 (2.0%)	11 816 (29.7%)	1136 (2.9%)	7367 (18.5%)	5005 (12.6%)	1690 (4.3%)	11 283 (28.4%)	720 (1.8%)	39 791
Stuttgart (242 240)	635 911	818 (2.0%)	11 755 (28.5%)	1203 (2.9%)	7842 (19.0%)	5355 (13.0%)	1838 (4.5%)	11 709 (28.4%)	778 (1.9%)	41 298
Leipzig (195.420)	593 145	747 (2.1%)	8937 (24.9%)	1069 (3.0%)	6243 (17.4%)	5348 (14.9%)	1728 (4.8%)	11 211 (31.2%)	671 (1.9%)	35.954
Dortmund (196 270)	588 250	728 (2.0%)	9926 (27.5%)	1098 (3.0%)	7313 (20.2%)	4622 (12.8%)	1732 (4.8%)	9980 (27.6%)	739 (2.1%)	36 139
Dresden (192 150)	556 780	711 (1.9%)	9361 (24.8%)	1149 (3.0%)	6721 (17.8%)	5562 (14.7%)	1879 (5.0%)	11 674 (31.0%)	724 (1.9%)	37 782
Hannover (192 530)	536 925	741 (1.9%)	10 154 (26.1%)	1248 (3.2%)	7649 (19.7%)	4954 (12.7%)	1930 (5.0%)	11 484 (29.5%)	771 (2.0%)	38 931
Nuremberg (173 350)	518 370	675 (1.9%)	9675 (26.6%)	1096 (3.0%)	6625 (18.2%)	4998 (13.7%)	1632 (4.5%)	10 988 (30.2%)	685 (1.9%)	36 374
Kiel (89 450)	246 794	835 (2.1%)	9603 (24.6%)	1329 (3.4%)	7946 (20.4%)	4943 (12.7%)	1896 (4.9%)	11 666 (29.9%)	754 (1.9%)	38 972
Magdeburg (76 550)	237 565	631 (1.8%)	7522 (21.4%)	1023 (2.9%)	6651 (18.9%)	5716 (16.3%)	1764 (5.0%)	11 130 (31.7%)	720 (2.1%)	35 157
Freiburg (100 220)	231 195	1051 (2.2%)	11 588 (24.8%)	1488 (3.2%)	8945 (19.1%)	6622 (14.1%)	2124 (4.5%)	14 148 (30.2%)	861 (1.8%)	46 826
Rostock (75 880)	209 191	736 (1.9%)	8801 (22.3%)	1128 (2.9%)	7409 (18.8%)	6157 (15.6%)	1893 (4.8%)	12 759 (32.3%)	631 (1.6%)	39 514
Saarbrücken (67 780)	180 374	710 (1.8%)	9114 (22.6%)	1.264 (3.1%)	8998 (22.3%)	5245 (13.0%)	1946 (4.8%)	12 374 (30.6%)	737 (1.8%)	40 388

Table 3 Results of the linear regression to assess the influence of selected environmental factors on the number of online searches in Germany from January 2016 to December 2019

Univariate	Monthly temperature (°C)	Monthly humidity (%)	Monthly sunshine duration (h)	Monthly precipitation (mm)	Monthly PM10 ^a (µg/m ³)
Beta (unstandardized)	-8.136	-0.422	-0.345	-0.121	-0.145
CI	[-9.791; -6.482]	[-1.096; 0.252]	[-0.485; -0.206]	[-0.481; 0.239]	[-1.784; 1.495]
P-value	<0.001	0.220	<0.001	0.510	0.862

^aInhalable particulate matter (PM) with diameters of 10 micrometers and smaller.

engine. In addition, only German-language web search queries were considered. This could lead to inaccuracies depending on the proportion of non-German language speakers in each city. Furthermore, Google does not provide general user demographic information so that no definite conclusions can be made about the population studied. In general, young people use the internet more often than older people.⁴⁴ Because AD is most

common in children, it is possible that some of the searches may not reflect the needs of affected children, but rather that of their concerned parents instead. Another limitation is that the search volume is provided and estimated by the search engine company without any possibility for verification by users. It should also be considered searches are not exclusively made by people affected by AD but also, for example, by physicians and medical students,

who make up a higher proportion of the population in smaller university cities with a medical faculty like Freiburg.

Conclusion

Internet search analyses have shown to help identify relevant disease characteristics and unmet needs for AD. The study demonstrated that there is an increasing interest in AD-related topics. In particular, the high search volume regarding therapy suggests a need for more information about the disease and its treatment options. Furthermore, the influence of climate on search volume indicates higher medical need during the winter months, which should be considered in everyday clinical healthcare and medical guideline development. Combining seasonal adjustment of treatment plans with holistic therapies and patient education programs can optimize effective AD management and improve future allocation of healthcare resources.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

- Weidinger S, Beck LA, Bieber T, Kabashima K, Irvine AD. Atopic dermatitis. *Nat Rev Dis Primers* 2018; **4**: 1.
- Nutten S. Atopic dermatitis: global epidemiology and risk factors. *Ann Nutr Metab* 2015; **66**(Suppl. 1): 8–16.
- Avena-Woods C. Overview of atopic dermatitis. *Am J Manag Care* 2017; **23**(8 Suppl): S115–S123.
- Kapur S, Watson W, Carr S. Atopic dermatitis. *Allergy Asthma Clin Immunol* 2018; **14**: 52.
- Garmhausen D, Hagemann T, Bieber T et al. Characterization of different courses of atopic dermatitis in adolescent and adult patients. *Allergy* 2013; **68**: 498–506.
- Drucker AM. Atopic dermatitis: burden of illness, quality of life, and associated complications. *Allergy Asthma Proc* 2017; **38**: 3–8.
- Kage P, Simon J-C, Treudler R. Atopic dermatitis and psychosocial comorbidities. *J Dtsch Dermatol Ges* 2020; **18**: 93–102.
- Karimkhani C, Dellavalle RP, Coffeng LE et al. Global skin disease morbidity and mortality: an update from the global burden of disease study 2013. *JAMA Dermatol* 2017; **153**: 406–412.
- Paller A, Jaworski JC, Simpson EL et al. Major comorbidities of atopic dermatitis: beyond allergic disorders. *Am J Clin Dermatol* 2018; **19**: 821–838.
- Brunner PM, Silverberg JJ, Guttman-Yassky E et al. Increasing comorbidities suggest that atopic dermatitis is a systemic disorder. *J Invest Dermatol* 2017; **137**(1): 18–25.
- Silverberg JJ. Atopic dermatitis in adults. *Med Clin North Am* 2020; **104**: 157–176.
- Bonamonte D, Filoni A, Vestita M, Romita P, Foti C, Angelini G. The Role of the environmental risk factors in the pathogenesis and clinical outcome of atopic dermatitis. *Biomed Res Int* 2019; **2019**: 1–11.
- Ibekwe PU, Ukou BA. Impact of weather conditions on atopic dermatitis prevalence in Abuja, Nigeria. *J Natl Med Assoc* 2019; **111**: 88–93.
- Sargen MR, Hoffstad O, Margolis DJ. Warm, humid, and high sun exposure climates are associated with poorly controlled eczema: PEER (Pediatric Eczema Elective Registry) cohort, 2004–2012. *J Invest Dermatol* 2014; **134**(1): 51–57.
- Patella V, Florio G, Palmieri M et al. Atopic dermatitis severity during exposure to air pollutants and weather changes with an Artificial Neural Network (ANN) analysis. *Pediatr Allergy Immunol* 2020; **31**: 938–945.
- Amante DJ, Hogan TP, Pagoto SL, English TM, Lapane KL. Access to care and use of the Internet to search for health information: results from the US National Health Interview Survey. *J Med Internet Res* 2015; **17**: e106.
- Beck F, Richard JB, Nguyen-Thanh V, Montagni I, Parizot I, Renahy E. Use of the internet as a health information resource among French young adults: results from a nationally representative survey. *J Med Internet Res* 2014; **16**: e128.
- Directorate-General for Communications Networks CaTEC. European Citizens' Digital Health Literacy, European Union, Brussels, Belgium, 2015.
- Verma M, Kishore K, Kumar M, Sondh AR, Aggarwal G, Kathirvel S. Google search trends predicting disease outbreaks: an analysis from India. *Health Inform Res* 2018; **24**: 300–308.
- Mavragani A, Ochoa G, Tsagarakis KP. Assessing the methods, tools, and statistical approaches in google trends research: systematic review. *J Med Internet Res* 2018; **20**: e270.
- Kaidashev I, Morokhovets H, Rodinkova V, DuBuske L, Bousquet J. Assessment of google trends terms reporting allergies and the grass pollen season in Ukraine. *World Allergy Organ J* 2020; **13**: 100465.
- Zink A, Schuster B, Rütth M et al. Medical needs and major complaints related to pruritus in Germany: a 4-year retrospective analysis using Google AdWords Keyword Planner. *J Eur Acad Dermatol Venerol* 2019; **33**: 151–156.
- Satista. Einwohnerzahl der größten Städte in Deutschland am 31. Dezember 2019. [WWW document]. URL <https://de.statista.com/statistik/daten/studie/1353/umfrage/einwohnerzahlen-der-grossstaedte-deutschlands/#professional> (last accessed: 28 October 2020).
- Bundesinstitut für Bau- Stadt- und Raumforschung. Indikatoren und Karten zur Raum- und Stadtentwicklung. [WWW document]. URL <https://www.inkar.de> (last accessed: 23 June 2021).
- Deutscher Wetterdienst. Deutscher Wetterdienst Climate Data Center. Offenbach, Germany. [WWW document]. URL <https://cdc.dwd.de/portal/> (last accessed: 15 June 2021).
- Bundesamt Umwelt. Current concentrations of air pollutants in Germany. [WWW document]. URL <https://www.umweltbundesamt.de/en/data/air/air-data/stations/ejzrXpScv9BwUXEykEhJXGVkYGipa2ika2y4qCRzkaHRorxUkGzJYmNDyyUpiW5FIBVmugaGQATkh-Qj60hOnNhGwDiiSYvKEIUX5VbxLspNblqck1hy2sEjceFdZ7kNi3Py0k87KKWKNzAwMAIAn5U6Kw==> (last accessed 15 June 2021).
- Thomas W, Werner A, Frank A et al. Leitlinie Neurodermitis [atopisches Ekzem; atopische Dermatitis]. *J Dtsch Dermatol Ges* 2016; **14**: e1–e75.
- Puar N, Chovatiya R, Paller AS. New treatments in atopic dermatitis. *Ann Allergy Asthma Immunol* 2021; **126**: 21–31.
- Li AW, Yin ES, Antaya RJ. Topical corticosteroid phobia in atopic dermatitis: a systematic review. *JAMA Dermatol* 2017; **153**: 1036–1042.
- Vieira BL, Lim NR, Lohman ME, Lio PA. Complementary and alternative medicine for atopic dermatitis: an evidence-based review. *Am J Clin Dermatol* 2016; **17**: 557–581.
- Shi K, Lio PA. Alternative treatments for atopic dermatitis: an update. *Am J Clin Dermatol* 2019; **20**: 251–266.
- Silverberg JJ, Margolis DJ, Boguniewicz M et al. Distribution of atopic dermatitis lesions in United States adults. *J Eur Acad Dermatol Venerol* 2019; **33**: 1341–1348.
- Marron SE, Cebrian-Rodriguez J, Alcalde-Herrero VM, Garcia-Latasa de Aranibar FJ, Tomas-Aragones L. Impacto psicossocial en adultos con dermatitis atópica: estudio cualitativo. *Actas Dermo-Sifiliogr (Engl Ed)* 2020; **111**: 513–517.
- Gochnauer H, Valdes-Rodriguez R, Cardwell L, Anolik RB. The psychosocial impact of atopic dermatitis. *Adv Exp Med Biol* 2017; **1027**: 57–69.

- 35 Capucci S, Hahn-Pedersen J, Vilsbøll A, Kragh N. Impact of atopic dermatitis and chronic hand eczema on quality of life compared with other chronic diseases. *Dermatitis* 2020; **31**: 178–184.
- 36 Zink A, Rùth M, Schuster B, Darsow U, Biedermann T, Ständer S. Pruritus in Germany—a Google search engine analysis. *Hautarzt* 2019; **70**: 21–28.
- 37 Tizek L, Schielein M, Rùth M *et al*. Influence of climate on google internet searches for pruritus across 16 german cities: retrospective analysis. *J Med Internet Res* 2019; **21**: e13739.
- 38 Lin T-K, Zhong L, Santiago JL. Association between stress and the HPA axis in the atopic dermatitis. *Int J Mol Sci* 2017; **18**: 2131.
- 39 Pavlis J, Yosipovitch G. Management of itch in atopic dermatitis. *Am J Clin Dermatol* 2018; **19**: 319–332.
- 40 Wollenberg A, Barbarot S, Bieber T *et al*. Consensus-based European guidelines for treatment of atopic eczema (atopic dermatitis) in adults and children: part II. *J Eur Acad Dermatol Venereol* 2018; **32**: 850–878.
- 41 Nguyen GH, Andersen LK, Davis MDP. Climate change and atopic dermatitis: is there a link? *Int J Dermatol* 2019; **58**: 279–282.
- 42 Krämer U, Weidinger S, Darsow U, Möhrenschrager M, Ring J, Behrendt H. Seasonality in symptom severity influenced by temperature or grass pollen: results of a panel study in children with eczema. *J Invest Dermatol* 2005; **124**: 514–523.
- 43 Ginsberg J, Mohebbi MH, Patel RS, Brammer L, Smolinski MS, Brilliant L. Detecting influenza epidemics using search engine query data. *Nature* 2009; **457**: 1012–1014.
- 44 Koch W. ARD/ZDF-Onlinestudie: Neun von zehn Deutschen Online 2017. [WWW document]. URL https://www.ard-zdf-onlinestudie.de/files/2017/Artikel/917_Koch_Frees.pdf