ORIGINAL REPORT

MJS PUBLISHING

ActaDV Acta Dermato-Venereologica ActaDV Advances in dermatology and venereology

Sociodemographic and Environmental Determinants of Regional Prevalence of Psoriasis in Germany: A Spatiotemporal Study of Ambulatory Claims Data

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There are regional differences in the prevalence of psoriasis between countries, as well as within countries. However, regional determinants of differences in prevalence are not yet understood. The aim of this study was to identify sociodemographic and environmental determinants of regional prevalence rates for psoriasis. Analyses were based on German outpatient billing data from statutory health insurance, together with data from databases on sociodemographic and environment factors at the county level (*N*=402) for 2015–2017. Descriptive statistics were calculated for all variables. To identify determinants for prevalence at the county level, spatiotemporal regression analysis was performed, with prevalence as the dependent variable, and the number of physicians, mean age, mean precipitation, sunshine hours, mean temperature, level of urbanity, and the German Index of Socioeconomic Deprivation (GISD) as independent variables. Mean prevalence of psoriasis increased from 168.63 per 10,000 in 2015 to 173.54 per 10,000 in 2017 for Germany as a whole, with high regional variation. Five determinants were detected ($p<0.05$). The prevalence increased by 4.18 per 10,000 persons with SHI with each GISD unit, and by 3.76 per 10,000 with each year increase in age. Each additional hour of sunshine resulted in a decrease of 0.04 and each °C increase in mean temperature resulted in an increase of 4.22. Each additional dermatologist per 10,000 inhabitants resulted in a decrease of 0.07. In conclusion, sociodemographic and environmental factors result in significant differences in prevalence of psoriasis, even within-country.

Key words: reginal variation; spatiotemporal regression analyses; prevalence difference; environmental factors; sociodemographic factors.

Submitted May 3, 2023. Accepted after review Nov 17, 2023

Published XX. DOI: 10.2340/actadv.v104.12430

Acta Derm Venereol 2024; 104: adv12430.

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SIGNIFICANCE

Psoriasis is a very common chronic skin disease with large variation in regional prevalence rates, which cannot be attributed only to genetic differences in the population. The current study therefore analysed sociodemographic and environmental factors that might influence regional prevalence rates, by means of spatio-temporal regression analyses and analysis of ambulatory claims data in Germany. The results showed that higher regional mean age, more social deprivation, less sunshine hours, and higher temperature were associated with higher regional prevalence rates of psoriasis.

Psoriasis is a very common, chronic, inflammatory skin disease with high costs-of-illness and high impact on health-related quality of life (1–3). The disease typically manifests in itchy, scaly, pruritic plaques of the skin, but can also affect the joints (4). It often goes along with severe comorbidities, such as diabetes mellitus, depression, or cardiovascular diseases (3, 5, 6). The prevalence of psoriasis varies significantly between different countries and regions around the world. Psoriasis prevalence correlates with latitude: the lowest prevalence rates occur in the equatorial region and the highest rates in northern Europe, Australia, and North America (7–11). Regional variations also exist at the country level. A study by Springate et al. (5) in the UK showed a north-south gradient with higher prevalence rates in the north of the UK. Similar tendencies were found in a recent study in Germany, with higher rates in the north and north-east and lower rates in the south (12).

However, causes of these regional differences in prevalence rates are unclear, as the aetiology of psoriasis is very complex and not fully understood. The disease is multifactorial and arises from a genetic predisposition interacting with epigenetic and non-genetic factors altering the functionality of the skin (13, 14).

On the one hand non-genetic factors can be lifestyle related. These include nutrition, tobacco and alcohol consumption, comorbidities, obesity, and others (14, 15). Those factors are often related to lower socioeconomic circumstances; hence more deprived regions with poorer inhabitants and worse health infrastructure would be expected to have higher prevalence rates of psoriasis. This association was found in a Swedish cohort study for several autoimmune disorders (16). On the other hand, non-genetic factors can be related to the living environment. Cold weather, low humidity, ultraviolet (UV) radiation, and air pollution can trigger the emergence of psoriasis and amplify the symptoms of the disease (17, 18).

Knowledge of the reasons for regional differences in prevalence of psoriasis can help decision-makers and providers to detect risk factors and therefore adjust and improve psoriasis care in Germany. The aim of this study was therefore to determine which regional (healthcare-) sociodemographic characteristics and environmental factors are associated with higher regional prevalence rates of psoriasis in Germany.

MATERIALS AND METHODS

Data-set and data preparation

Psoriasis data. All data were analysed at the regional level of the 402 German national counties (*Nomenclature des unités territoriales statistiques*; NUTS 3) (19). For psoriasis prevalence, the National Association of Statutory Health Insurance Physicians (*Kassenärztliche Bundesvereinigung*; KBV) provided nationwide ambulatory claims data from 2015 to 2017 on billed psoriasis diagnoses according to the International Statistical Classification of Diseases and Related Health Problems – 10th revision (ICD-10)). As this study used only secondary data on an aggregated level, no ethics approval was necessary for. Included were all people (age 18 years and older) covered by statutory health insurance (SHI). SHI covers approximately 90% of the German population, with SHI applying to approximately 72.8 million persons. In accordance with recommendations for analysing chronic diseases in routine data, cases were defined as having at least 2 confirmed billed diagnoses in different quarters within 1 year (minimum 2 quarters; M2Q criteria) to avoid the overestimation of prevalence due to misdiagnosis (20). Prevalence rates for each county are directly age- and sex-standardized, using all people with SHI with at least 1 medical doctor consultation in the respective year. The place of patient's residence served as regional reference.

Sociodemographic data. For regional sociodemographic characteristics the German Index of Socioeconomic Deprivation (GISD), developed by the Robert Koch Institute (RKI), Germany's central scientific institution in the field of biomedicine, was applied (21). The GISD includes 8 indicators in the 3 dimensions education, occupation, and income. We included the 5-point scale version in the analyses (1: low regional depravation; 5: high regional deprivation). The GISD is available only for 2017. Assuming that socioeconomic deprivation is a slowly changing construct, the score for all years was used. In addition, the study included the regional mean age in years, which was also accessed via the Indicators and maps for spatial and urban development (german: Indikatoren und Karten zur Raum- und Stadtentwicklung, INKAR) database of the Institute for Research on Building, Urban Affairs and Spatial Development (*Bundesinstitut für Bau-, Stadt- und Raumforschung*; BBSR) (22). As a measure of urbanity, the official scale (range 1–4) for settlement structure types of the BBSR was included: 1: counties being big cities; 2: urban counties; 3: rural counties showing densification; and 4: sparsely populated rural counties (23).

Environmental data. Environmental data on temperature, precipitation, and sunshine hours were available from the Climate Data Center (CDC) (24) of Germany's National Meteorological Service (*Deutscher Wetterdienst*; DWD) on raster level, considering high dependencies. Raster divide the geographical surface into regular cells of identical size. They were transformed into county level. For temperature, the study used annual mean temperature, winter mean temperature (December, January, February), and summer mean temperature (June, July, August) for the years 2015 to 2017. Temperature is specified in degree Celsius (°C). The study had no access to data on humidity at the county level, and precipitation data were included as an alternative. The annual sum (in mm) of monthly precipitation for Germany was used. The study had no access to nationwide data on UV radiation; hence sunshine hours were used as an alternative. The annual sum of the monthly rates from the DWD was used.

Healthcare data. Because prevalence is measured in billing frequencies, it is assumed that the number of billing physicians may have an influence. Therefore, the study included the regional density of physicians as control variables. In Germany, not only dermatologists, but also general practitioners (GPs) and other specialties, may treat psoriasis. Hence, the study included the regional density of all physicians, GPs, and dermatologists. Data on the density of all physicians and GPs per 10,000 inhabitants at the country level were available for all years in the INKAR data. Data on the density of dermatologists were not available from INKAR. Therefore, these data were accessed via the database of the Central Research Institute of Ambulatory Health Care in the Federal Republic of Germany (*Zentralinstitut für die kassenärztliche Versorung in Deutschland*; Zi) (25). Data on dermatologists are available at the county level per 100,000 inhabitants. Therefore the data were converted into *n* per 10,000 inhabitants.

Descriptive statistics

For each year and each variable, the mean with standard deviation (SD), minimum, maximum, and extremal quotient (EQ) were calculated. The EQ is the result of dividing the maximum value by the minimum value. By showing the ratio of the area with the highest value and the area with the lowest, it is an expression of the regional variations (26). Here, we used values within the 1% and 99% percentiles to avoid the influence of outliers. This method is not applicable for negative values. For the prevalence of psoriasis and the significant determinants, maps of regional frequencies at the county level were plotted.

Spatiotemporal regression

To identify regional determinants of the psoriasis prevalence rates at the county level, multivariate spatially autocorrelated first-order process regression analyses were performed (27–29). The inference is based on Bayesian statistics using Markov chain Monte Carlo (MCMC) simulations, which was run for 2,200,000 samples. This procedure was performed 3 times, producing 3 different simulations with independent Markov chains. The posterior median point estimate (median) and 95% credible intervals are reported from the model, which are computed from the results of the 3 simulations together. In the spatiotemporal regression model, the chosen binary neighbourhood matrix takes dependencies of adjacent neighbours into account and controls for spatial and temporal autocorrelation of the dependent variable. The age- and sex-standardized prevalence rate of psoriasis at the county level was set as dependent variable. This rate does not follow a Poisson distribution, and therefore, a Gaussian model was performed. As independent variables, the above-mentioned variables at the county level were included (**Fig. 1**). The variable selection for the model was conducted backward stepwise and significant variables remained in the model.

All data analyses were carried out using R Core Team R (R Foundation for Statistical Computing, Vienna, Austria) (30) and QGIS 3.22.1-Białowieża (QGIS Development Team, QGIS Geographic Information System. Open Source Geospatial Foundation Project).

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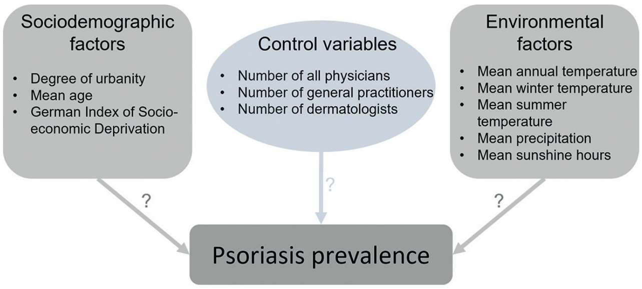

Fig. 1. Structure of the spatiotemporal regression model with independent and dependent variables.

RESULTS

Descriptive statistics

The mean age- and sex-standardized prevalence of psoriasis increased from 168.63 per 10,000 inhabitants in 2015 to 173.54 per 10,000 in 2017, with a slightly decreasing EQ from 2.57 to 2.49. The number of physicians per 10,000 was stable over the time, with a mean of 14.58 for all physicians, 6.37 for GPs, and 0.46 for dermatologists in 2017. The mean age increased from 44.35 years in 2015 to 44.54 in 2017. The values for precipitation and sunshine hours fluctuated, with a mean of 854.54 mm depth of precipitation and 1593.92 h of sunshine in 2017. Temperatures fluctuated, with an annual mean of 9.76°C, a summer mean of 18.17°C, and a winter mean of 1.06°C in 2017. The mean settlement structure score was 4 (median 3) and the mean GISD 3.17 (median 3) (**Table I**). The regional distribution of psoriasis prevalence and significant variables is shown in **Fig. 2**.

Spatiotemporal regression

The Geweke diagnostic for MCMC convergence showed values between –1.4 and 1.6, and therefore met model fit criteria for the regression analyses (28, 31). The spatiotemporal regression models identified regional determinants for the counties' psoriasis prevalence rates. The final model with 3 simulations included 5 significant independent variables: GISD, age, sunshine hours, annual temperature, and number of dermatologists (Fig. 2). Each unit increase on the GISD scale (scale range 1–5) resulted in an increase in county psoriasis of 4.177 and each year older in mean age resulted in an increase of 3.763 per 10,000 statutory health insured persons. With each extra mean hour of sunshine, the prevalence decreased approximately 0.039 and with each °C higher in temperature, the prevalence increased by 4.218 per 10,000 persons with SHI. Each additional dermatologist per 10,000 resulted in a prevalence decrease of 0.070 per 10,000 persons with SHI. The other independent variables did not show an effect on regional variation in the psoriasis prevalence at the county level. These were removed from the model in the course of the backward stepwise regression, as their credible intervals covered zero and therefore their associations were not significant (**Table II**).

DISCUSSION

This study aimed to identify sociodemographic and environmental determinants for the regional prevalence of psoriasis. The applied spatiotemporal model, using several national databases in a multi-source approach, detected regional socioeconomic deprivation, mean age, annual mean temperature, and annual sunshine hours as significant factors influencing the prevalence of psoriasis.

The association between higher regional socioeconomic deprivation and higher prevalence of autoimmune disorders, including psoriasis, was also found in a Swe-

Table I. Descriptive characteristics of included variables at the county level

Variable (County-level data)	2015			2016			2017		
	Mean (SD)	Range	EQ*	Mean (SD)	Range	EQ*	Mean (SD)	Range	EQ*
Psoriasis prevalence, per 10,000 statutory health insured persons	168.63 (36.39)	95.3–330.1	2.57	171.92 (36.56)	99.9–339.6	2.53	173.54 (37.06)	93.8–340.9	2.49
All physicians, per 10,000 inhabitants	14.63 (4.48)	7.31–30.83	3.50	14.61 (4.43)	7.35–30.45	3.40	14.58 (4.40)	7.33–30.46	3.36
General practitioners, per 10,000 inhabitants	6.37 (0.72)	4.76–9.42	1.73	6.39 (0.69)	4.81–9.45	1.71	6.37 (0.66)	4.81–9.03	1.63
Dermatologists, per 10,000 inhabitants	0.46 (0.28)	0.0–1.81	n.a.	0.45 (0.28)	0.0–1.99	n.a.	0.46 (0.29)	0.0–1.90	n.a.
Age, inhabitants mean, years	44.35 (1.88)	39.76–49.45	1.21	44.48 (1.93)	39.73–49.8	1.22	44.54 (1.96)	39.81–50.01	1.23
Precipitation, mean, depth, mm	697.81 (185.50)	369.33–1,557.47	3.35	755.85 (214.53)	400.29–1,847.46	3.67	854.54 (207.03)	500.44–2,084.22	3.41
Sunshine hours, mean per year	1740.05 (97.28)	1,512.26–1,983.15	1.22	1,593.92 (75.94)	1,382.83–1,792.74	1.09	1,593.92 (75.94)	1,382.83–1,792.74	1.09
Temperature, in °C mean per year	10.10 (0.79)	6.88–12.01	1.46	9.68 (0.81)	6.47–11.36	1.49	9.76 (0.88)	6.28–11.66	1.54
Summer temperature, in °C mean (June to August)	18.63 (1.12)	15.91–21.23	1.30	17.90 (0.83)	14.31–19.98	1.24	18.17 (0.97)	15.38–20.71	1.27
Winter temperature, in °C mean (December to February)	2.00 (1.08)	–1.61–3.97	n.a.	3.84 (1.11)	0.39–6.41	5.32	1.06 (1.41)	–2.50–3.94	n.a.
Settlement structure, scale 1–4	2.60 (1.04)	1–4	4.00	2.60 (1.04)	1–4	4.00	2.60 (1.04)	1–4	4.00
German Index of Socioeconomic Deprivation, scale 1–5	3.17 (1.40)	1–5	5.00	3.17 (1.40)	1–5	5.00	3.17 (1.40)	1–5	5.00

*Within the 1% and 99% percentiles; n.a., not applicable as the EQ cannot be determined for values ≤0.
SD: standard deviation; EQ: extremal quotient.

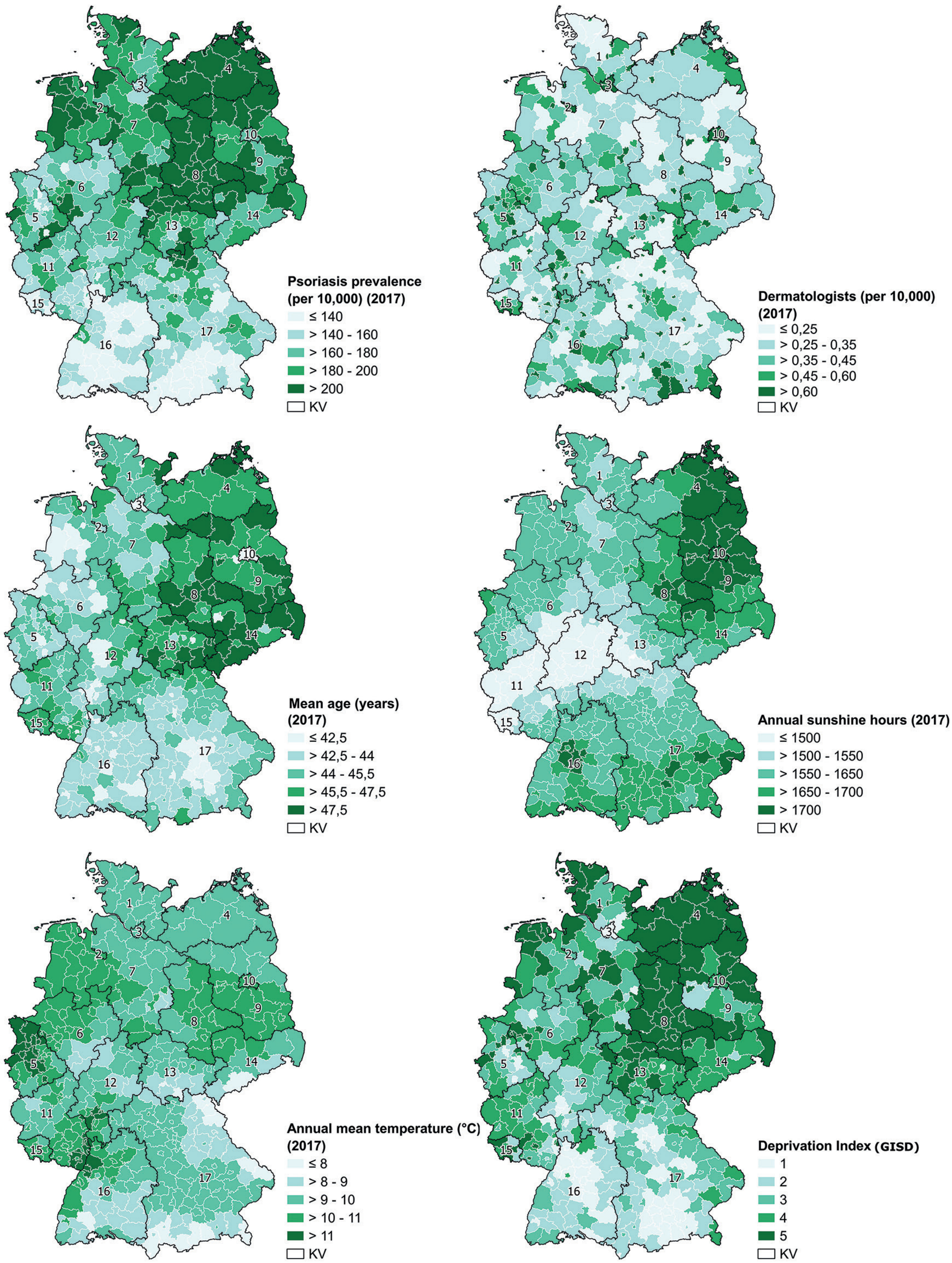

Fig. 2. Spatial trends for psoriasis prevalence rates, number of dermatologists, mean age, sunshine hours, mean temperature and deprivation index in 2017. 1 Schleswig-Holstein; 2 Bremen; 3 Hamburg; 4 Mecklenburg-Western Pomerania; 5 North Rhine; 6 Westphalia-Lippe; 7 Lower Saxony; 8 Saxony-Anhalt; 9 Brandenburg; 10 Berlin; 11 Rhineland-Palatinate; 12 Hesse; 13 Thuringia; 14 Saxony; 15 Saarland; 16 Baden-Württemberg; 17 Bavaria. KV: regions of the association of statutory health insurance physicians which resemble the federal states.

dish study (16). The underlying reasons for this could be manifold. Possible explanations can be higher risk for lifestyle triggers, such as psychological stress, obesity, smoking, low income, and less healthy nutrition in more deprived areas (15, 16, 32, 33). The association of higher mean age with higher psoriasis prevalence rate at the county level is supported by the literature. Psoriasis is a chronic disease with onset often in adult age; hence there is more psoriasis in older populations (9). In the current study, this finding is of special interest, as the

Table II. Results of spatiotemporal regression analysis at county level

Independent variable	Posterior median point estimate	2.5%–97.5% Credible interval
German Index of Socioeconomic Deprivation, scale 1–5	4.177	3.026–5.580
Age, inhabitants mean, years	3.763	2.662–4.818
Sunshine hours, mean per year	−0.039	−0.070 to −0.006
Temperature, in °C mean per year	4.218	1.420–7.082
Dermatologists, per 10,000 inhabitants	−0.070	−0.123 to −0.011

prevalence rates utilized were already aged-standardized. This indicates that regions of older age per se are more susceptible to psoriasis risk factors.

The environmental determinants for psoriasis may initially appear contradictory: higher temperatures are associated with higher prevalence rates and more sunshine hours with lower prevalence rates. However, these factors are not necessarily geographically related. Fig. 2 shows that, in Germany, sunshine hours and temperature are not closely related. The relationship between sunshine hours as a proxy for UV radiation and psoriasis is suggestive, as the association of less psoriasis with higher UV radiation is well known, and UV light is also used as therapy (34, 35). It is notable that individual's skin can respond differently to UV light, depending, for example, on their diet or the length of time of UV exposure (36, 37). In addition to crude UV exposure, the production of vitamin D might be an additional factor for the association between sunshine hours and psoriasis, as vitamin D uptake firstly occurs via sunshine exposure. Associations between low vitamin D level and psoriasis have been observed (38).

Literature on psoriasis and temperature is rare and controversial. Worldwide studies show lower prevalence rates in warmer regions (8, 9, 11, 39); however, this might also be due to the association with UV radiation in those regions. The current study found warmer temperatures to be associated with higher prevalence rates. This might be due to the effect of sweating on the skin, as well as a risk of heat intolerance among psoriatic patients (40). Since the magnitude of the effect is unclear, and since there is a lack of data on environmental temperature acting on the skin in the population, this topic is subject to further investigation. In contrast, precipitation did not show an effect on the prevalence of psoriasis in this model. This might be because precipitation is not directly associated with psoriasis and was used as a proxy for humidity. Low humidity, however, is known to be associated with higher prevalence rates of psoriasis (17). For all environmental factors, it should be noted that Germany is geographically a relatively small country with less substantial differences in environmental conditions, such that environmental effects are rather low in this analysis.

As this study utilizes billing data, we controlled for the number of physicians in the county that could bill the diagnosis of psoriasis. Notably, GPs and all physicians have no influence on the prevalence, whereas the number of dermatologists has a very small influence. That the prevalence decreases with increasing number of dermatologists might be due to our M2Q criteria for case definition. Because of this definition, cases that are treated at the dermatologist and are treated so well there that they visit the doctor less often could end up not recorded here.

One limitation of this study is the use of accumulated data at the county level, which could lead to ecological fallacy. However, as this accumulation is on a small spatial scale, the results are relatively reliable. A further limitation of such geographical exposure studies is the lack of control for absences from the place of residence. Here, individual travel behaviour or previous residence may confound the regional effects, as has been shown for skin cancer (41). Another important aspect is the use of billing data. There is a chance of underestimating the real-world prevalence, as people with mild psoriasis might not seek medical treatment. Nevertheless, because the study used a nationwide dataset, covering approximately 90% of the population with equal healthcare access, there is only a low risk of bias for the temporal and spatial analyses. This large dataset, including time series and several important determinants is a major strength of this study. In combination with the complex and thorough methodology, the application of this dataset has a strong significance.

In conclusion, the occurrence of psoriasis is associated with a highly complex combination of internal and external factors. The external factors can be sociodemographic and environmental and can cause, even within small areas, very different prevalence rates. In order to optimize prevention and healthcare of psoriasis it is important to detect the exposure factors that can trigger psoriasis, and understand their regional occurrence.

ACKNOWLEDGEMENTS

We would like to thank the Scientific Communication Team of the IVDP, in particular Mario Gehoff and Amber Hönning, for copyediting. In addition, we thank the National Association of Statutory Health Insurance Physicians (*Kassenärztliche Bundesvereinigung*; KBV) in Germany for providing and processing the ambulatory care claims data.

We acknowledge financial support from the Open Access Publication Fund of UKE - Universitätsklinikum Hamburg-Eppendorf and DFG – German Research Foundation.

The authors have no conflicts of interest to declare.

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