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Temporal and Spatial Trends in the Global Burden of Acne Vulgaris Among Women of Reproductive Age: A Comprehensive Analysis and Forecast From 1990 to 2040

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ABSTRACT

Background: Acne is a common, multifactorial skin condition with significant psychosocial and public health impacts. However, its burden among reproductive-age women remains underexplored.

Methods: Using Global Burden of Disease (GBD) 2021 data, we analyzed acne incidence, prevalence, and disability-adjusted life years (DALYs) in females aged 15–49 across 204 countries (1990–2021). Trends were assessed via age-standardized rates and estimated annual percentage change (EAPC). Decomposition and inequality analyses identified contributing factors. Bayesian age-period-cohort (BAPC) modeling projected trends to 2040.

Results: From 1990 to 2021, acne incidence, prevalence, and DALYs rose by 34%, 38%, and 37%, respectively. The greatest increases occurred in low-socio-demographic index (SDI) regions (e.g., Sub-Saharan Africa). The 15–19 age group had the highest burden, but older age groups showed faster growth. Population growth was the key driver. Inequalities narrowed overall but remained complex. Projections show continued burden growth by 2040.

Conclusions: The acne burden among reproductive-age women is increasing globally, especially in low-SDI regions and adolescents, underscoring the need for targeted strategies.

1 | Introduction

Acne vulgaris is a chronic inflammatory skin disorder and one of the most prevalent dermatologic conditions globally, with substantial implications for public health [1]. It is a multifactorial disease influenced by hormonal fluctuations, genetic predisposition, and

environmental exposures [2]. Emerging evidence further implicates air pollution, dietary habits, and climate change in aggravating acne, particularly in urban settings [3–5]. Beyond its physical manifestations, acne can severely affect quality of life, contributing to reduced self-esteem, body image concerns, and heightened risks of anxiety, depression, and other mental health disorders [6].

Abbreviations: ASIR, age-standardized incidence rate; ASPR, age-standardized prevalence rate; ASR, age-standardized rate; BAPC, Bayesian Age-Period-Cohort; CI, Concentration Index; DALYs, disability-adjusted life years; EAPC, estimated annual percentage change; GBD, Global Burden of Disease; ICD, International Classification of Diseases; INLA, Integrated Nested Laplace Approximation; SDI, Socio-Demographic Index; SII, Slope Index of Inequality; UV, ultraviolet.

Jie Yan and Yuzhou Cai contributed equally to this Work.

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Despite its high prevalence, existing epidemiological studies primarily focus on traditional high-risk populations, such as adolescents [7]. However, acne is increasingly affecting adult women, who often exhibit distinct clinical features, treatment responses, and psychosocial impacts compared to younger individuals [7, 8]. Notably, up to 45% of women aged 21–30 and 12% of those aged 41–50 experience acne [9]. Yet, studies specifically examining acne among women of reproductive age remain limited, especially regarding global spatiotemporal trends.

The growing availability of high-quality datasets, such as the Global Burden of Disease (GBD) Study, provides unprecedented opportunities to assess disease distribution, trends, and determinants across populations. While acknowledging the limitations of modeled estimates—particularly in data-scarce regions—GBD remains the most comprehensive source for understanding global health patterns. These data facilitate exploration of acne's association with sociodemographic status, healthcare infrastructure, and environmental risk factors.

This study utilizes the GBD 2021 dataset to assess global, regional, and national trends in the burden of acne vulgaris among women of reproductive age from 1990 to 2021. Through rigorous epidemiological analysis and statistical modeling, we aim to identify key drivers of burden and inform targeted clinical and policy interventions [10].

2 | Materials and Methods

2.1 | Data Source

This study utilized data from the Global Burden of Disease Study 2021 database (<https://ghdx.healthdata.org/gbd-2021>), which provides comprehensive estimates for 204 countries and territories, 371 diseases and injuries, and 88 risk factors. We extracted data on incidence, prevalence, and disability-adjusted life years (DALYs) for acne vulgaris among women of reproductive age (15–49 years) from 1990 to 2021 [10–13].

2.2 | Disease Definition

Acne vulgaris is classified under the noncommunicable diseases category in the GBD 2021 hierarchy, specifically under skin and subcutaneous diseases. It corresponds to the International Classification of Diseases (ICD)-10 code L70 and ICD-11 code ED80 [10, 13].

2.3 | Statistical Analysis

We calculated age-standardized rates (ASRs) for incidence, prevalence, and DALYs using the GBD 2021 world standard population. The estimated annual percentage change (EAPC) was computed to quantify temporal trends in ASRs. We employed a log-linear regression model: $\ln(\text{ASR}) = \alpha + \beta \times \text{year} + \epsilon$, where β represents the EAPC.

To assess health inequalities, we used the Slope Index of Inequality (SII) for absolute disparities and the concentration index for

relative inequalities (range: -1 to 1 , with 0 indicating equality). Decomposition analysis attributed changes in disease burden to population growth, aging, and epidemiological shifts. The sociodemographic index (SDI) was applied to examine development-related patterns, using locally estimated scatterplot smoothing (LOESS) and Spearman's rank correlation for trend visualization and association analysis. Future projections (2022–2040) employed a Bayesian age-period-cohort (BAPC) model via the integrated nested Laplace approximation (INLA). All analyses were conducted in R v4.4.1 using standard packages, with significance set at $p < 0.05$.

3 | Results

3.1 | Sociodemographic Disparities in Acne Vulgaris Burden Among Women of Reproductive Age: A Global Analysis

The global burden of acne vulgaris among reproductive-age women significantly increased between 1990 and 2021 (Figures 1, S1 and S2, Tables S1–S4). Incidence rose by 34%, from 23.1 to 31.0 million cases, with a 4% increase in age-standardized incidence rates (ASR; Table S1). Prevalence increased by 38%, from 65.0 to 89.3 million cases, accompanied by an 8% rise in ASR (Table S3). DALYs attributed to acne rose by 37%, from 1.38 to 1.90 million, also with an 8% increase in ASR (Table S4). EAPC indicated consistent upward trends (0.17%–0.28%).

3.2 | Sociodemographic Disparities in Acne Vulgaris Burden Among Women of Reproductive Age: A 5-SDI Region Analysis

Acne vulgaris among women of reproductive age exhibited notable sociodemographic disparities from 1990 to 2021 (Figures 1, S1 and S2, Tables S1, S3, and S4). Low-SDI regions had the largest increases in incidence (180%), prevalence (182%), and DALYs (183%), with substantial rises in age-standardized rates (ASR: 14%–16%) and high estimated annual percentage changes (EAPC: 0.46–0.64). Conversely, high-SDI regions showed minimal growth (incidence 2%, prevalence 4%, DALYs 3%, ASR: 1%–5%, and EAPC: 0.05–0.10), while high-middle SDI regions slightly declined in incidence, prevalence, and DALYs (–3% to –4%).

3.3 | Global Disparities in Acne Vulgaris Burden Among Women of Reproductive Age: A 21-Region Analysis

Acne vulgaris among reproductive-age women exhibited marked disparities across 21 global regions from 1990 to 2021 (Figures 1, 2, S1 and S2, Tables S1–S4). Western Sub-Saharan Africa saw the greatest incidence increase (206%; cases rising from 720,594 to 2,203,121; ASR +13%; EAPC: 0.43 [95% CI: 0.40–0.46]; Table S1), while high-income Pacific Asia experienced the largest incidence decline (23%; from 1,203,821 to 927,249 cases), despite a 6% ASR increase (EAPC: 0.31 [95% CI: 0.24–0.37]). Prevalence rose significantly in South Asia (102%; from 9.1 to 18.5 million cases; ASR +18%; EAPC: 0.69 [95% CI: 0.59–0.79]; Table S3). DALY trends paralleled incidence and prevalence, with notable increases in Sub-Saharan Africa and stability or slight declines in high-income regions (Table S4).

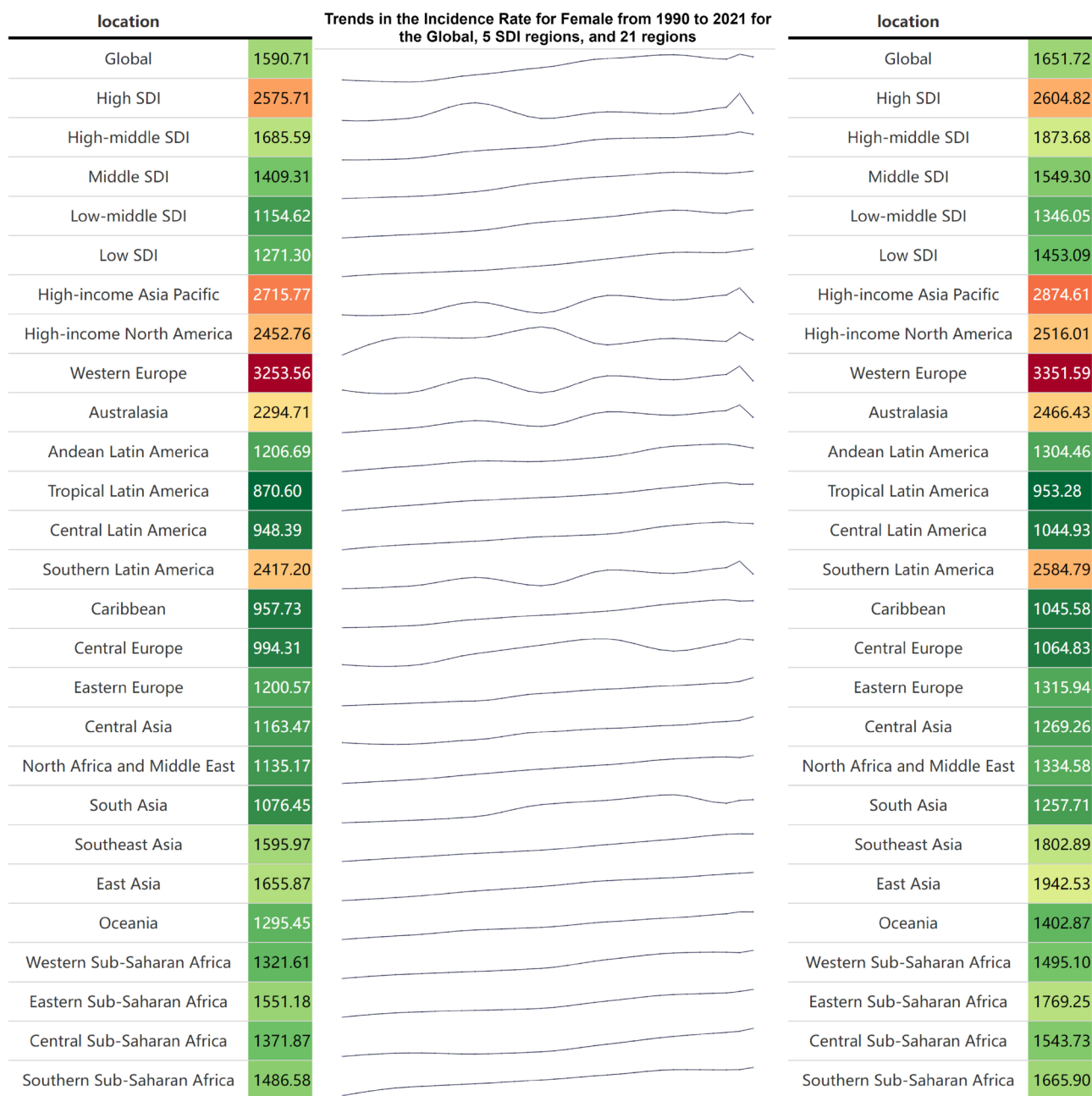


FIGURE 1 | Global, SDI-specific, and regional trends in age-standardized incidence rates of acne vulgaris among women of reproductive age, 1990–2021.

3.4 | Global Heterogeneity in Acne Vulgaris Burden Among Women of Reproductive Age: A 204-Country Analysis

Acne vulgaris among reproductive-age women displayed notable disparities across 204 countries from 1990 to 2021 (Figures 3 and S3, Tables S4–S7). Equatorial Guinea showed the largest increases in incidence (362%; cases: 1602 to 7399; ASR +29.63%; EAPC: 0.91 [95% CI: 0.88–0.95]; Table S5), prevalence (354%; cases: 5089 to 23,106; ASR +28.87%; Table S6), and DALYs (357%; ASR +29.90%; Table S7). Oman and Sudan also exhibited substantial increases (> 160% in incidence and prevalence). Conversely, Poland had the greatest incidence decline (–25.70%; ASR –1.10%; EAPC: –0.07 [95% CI: –0.14 to –0.01]), and Germany experienced a prevalence reduction (–12.09%), despite a modest rise in prevalence rates (+4.11%).

DALY trends mirrored incidence and prevalence, with significant increases in Equatorial Guinea, Oman, and Sudan, and minor changes in countries such as Germany, Switzerland, and New Zealand.

3.5 | Age-Specific Patterns of Acne Vulgaris Burden Among Women of Reproductive Age: A Global Perspective

Acne vulgaris among reproductive-age women displayed significant disparities by age from 1990 to 2021 (Figures 4, 5, and S3, Tables S2, S6, and S7). The 15–19 age group had the highest burden, with incidence rising by 28% (cases: 12.4–15.9 million; ASR +8%; EAPC: 0.32 [95% CI: 0.29–0.35]; Table S2),

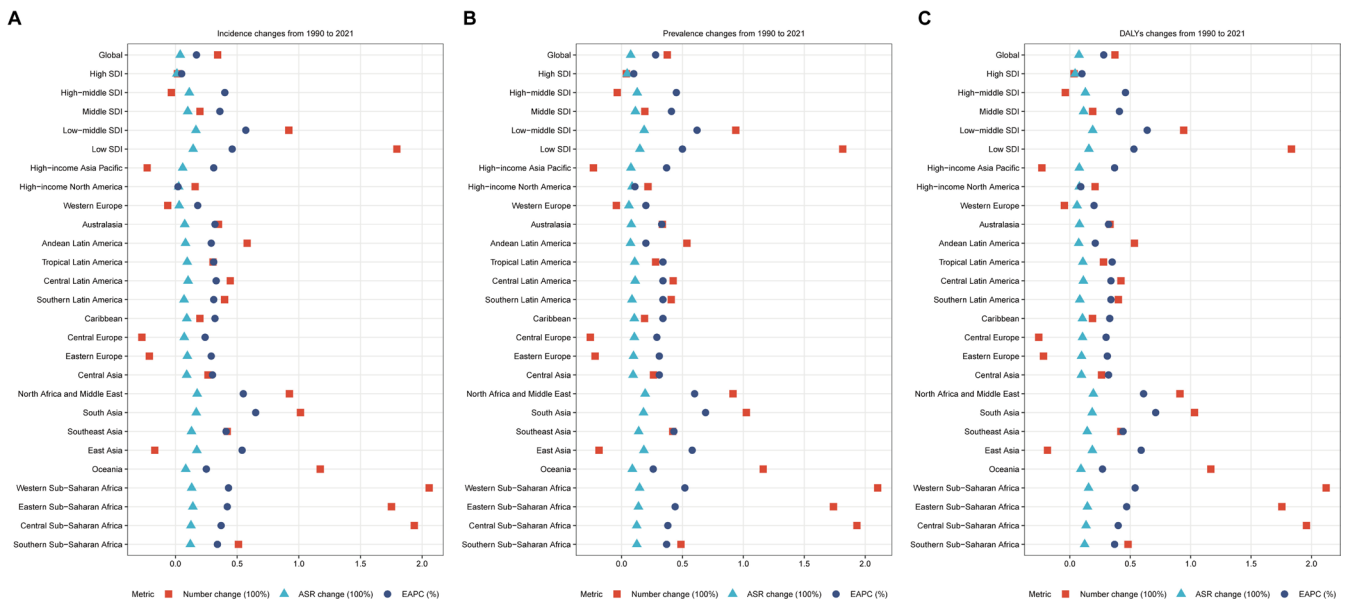


FIGURE 2 | Percentage changes and EAPC in acne vulgaris burden among women of reproductive age, 1990–2021. (A) Global, SDI-specific, and regional changes in incidence numbers, rates, and EAPC. (B) Global, SDI-specific, and regional changes in prevalence numbers, rates, and EAPC. (C) Global, SDI-specific, and regional changes in DALY numbers, rates, and EAPC.

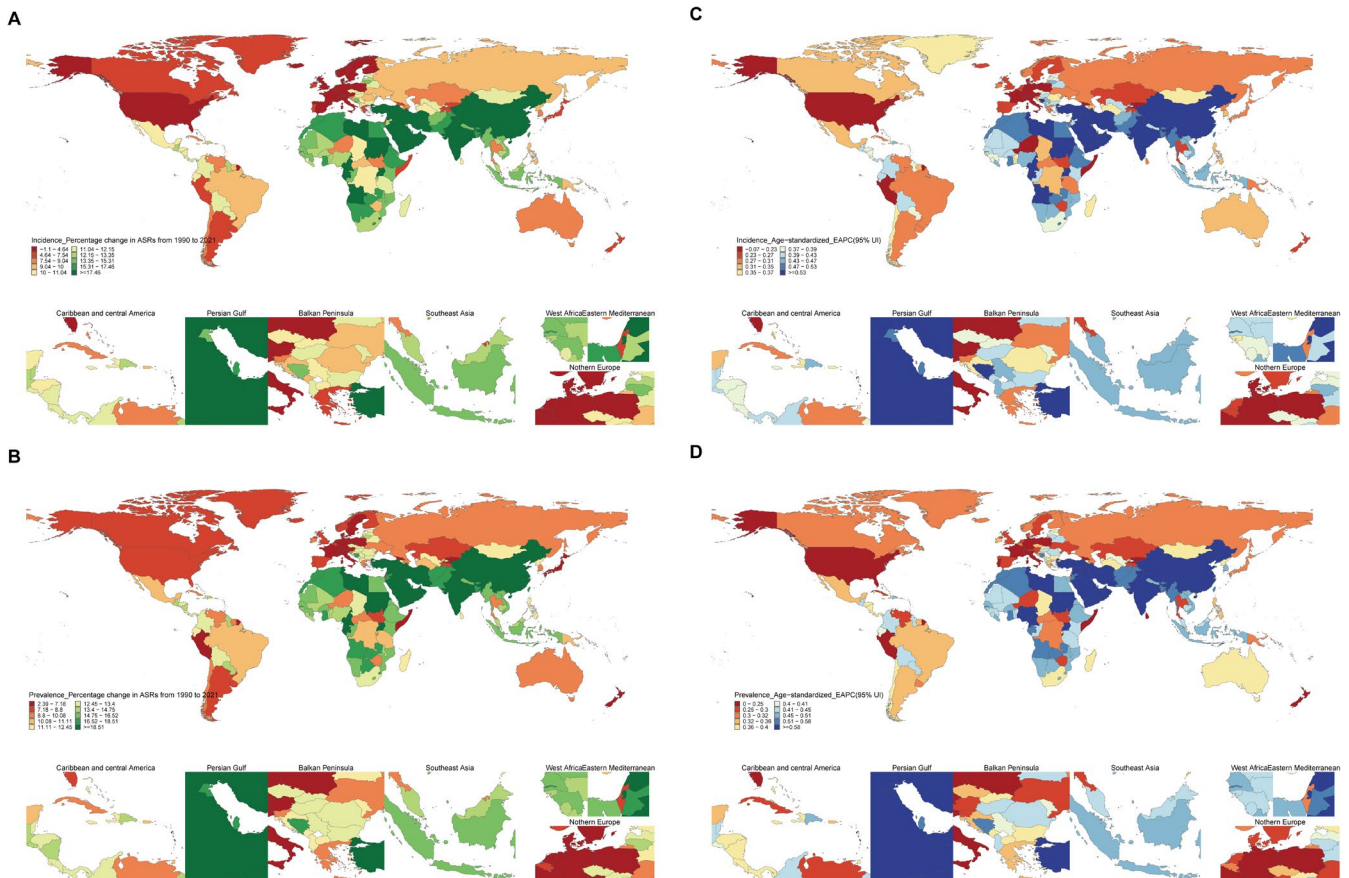


FIGURE 3 | National-level EAPC in acne vulgaris burden among women of reproductive age, 1990–2021. (A) Age-standardized incidence rates across 204 countries and territories. (B) Age-standardized prevalence rates across 204 countries and territories. (C) EAPC in age-standardized incidence rates across 204 countries and territories. (D) EAPC in age-standardized prevalence rates across 204 countries and territories.

prevalence increasing by 35% (ASR +13.58%; EAPC: 0.46 [95% CI: 0.44–0.48]; Table S6), and DALYs similarly increasing by 35% (ASR +14%; Table S7). While burden decreased with age, the 45–49 group showed the greatest relative increase in

cases (108%), but only a slight ASR rise (+0.48%). In contrast, the 30–44 age groups experienced slight declines across incidence, prevalence, and DALY rates, with negative EAPC values.

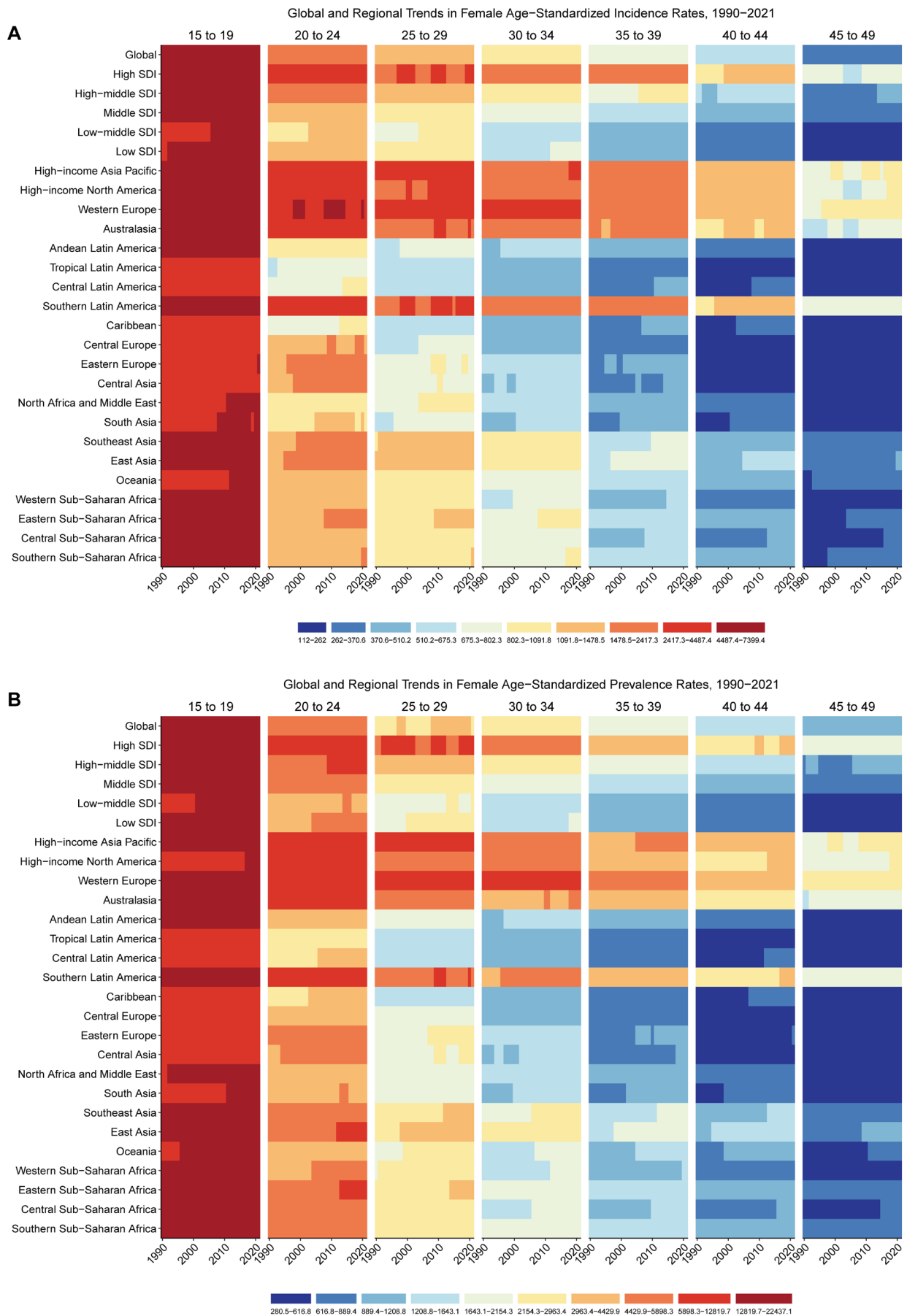


FIGURE 4 | Age-specific trends in acne vulgaris burden among women of reproductive age, 1990–2021. (A) Global, SDI-specific, and regional trends in age-specific incidence rates. (B) Global, SDI-specific, and regional trends in age-specific prevalence rates.

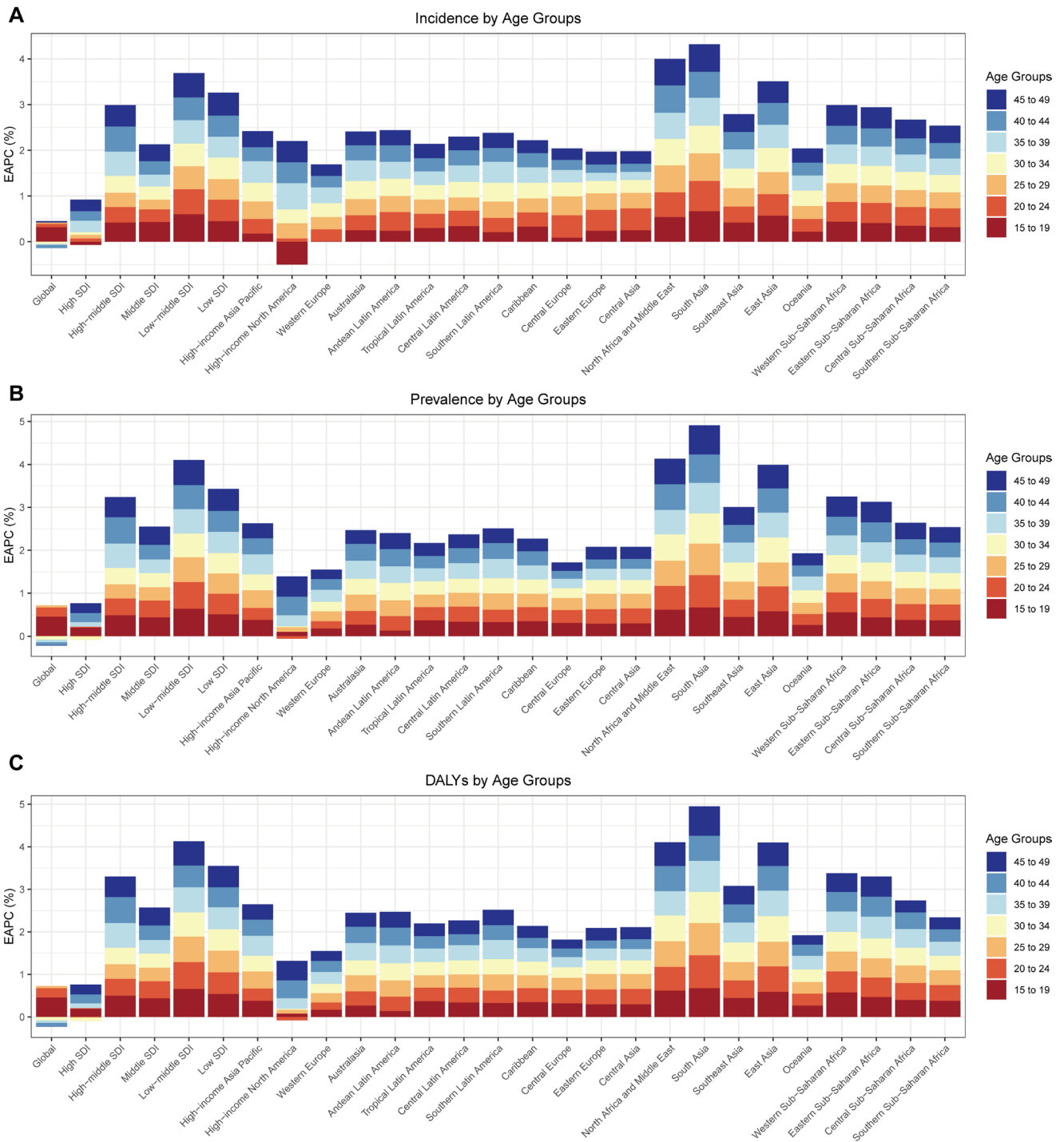


FIGURE 5 | Trends in acne vulgaris among women of reproductive age from 1990 to 2021. (A) EAPC in incidence rates globally, in 5 SDI regions, and 21 world regions, stratified by age group. (B) EAPC in prevalence rates globally, in 5 SDI regions, and 21 world regions, stratified by age group. (C) EAPC in DALY rates globally, in 5 SDI regions, and 21 world regions, stratified by age group.

3.6 | Age-Specific and Sociodemographic Disparities in Acne Vulgaris Burden Among Women of Reproductive Age: A 5-SDI Region Analysis

Acne vulgaris among reproductive-age women showed marked disparities across SDI regions and age groups from 1990 to 2021 (Figures 4, 5, and S3, Tables S2, S6 and S7). The greatest increases occurred in low-SDI regions, especially among adolescents. In the 15–19 age group, incidence rose by 180% (ASR

+14%; EAPC: 0.45 [95% CI: 0.42–0.49]), while high-SDI regions saw a 12% decline (ASR –4%; EAPC: –0.07 [95% CI: –0.13 to –0.02]; Table S2). Prevalence in low-SDI regions rose by 183% (ASR +15.43%; EAPC: 0.51 [95% CI: 0.48–0.55]), compared to only 2% in high-SDI regions (ASR +7.60%; EAPC: 0.20 [95% CI: 0.15–0.24]; Table S8). DALYs showed similar patterns: low-SDI regions increased by 185% (ASR +16%; EAPC: 0.54 [95% CI: 0.50–0.57]), whereas high-SDI regions rose only 2% (ASR +7%; EAPC: 0.19 [95% CI: 0.15–0.23]; Table S9).

3.7 | Age-Specific and Regional Disparities in Acne Vulgaris Burden Among Women of Reproductive Age: A 21-Region Analysis

Between 1990 and 2021, acne vulgaris among reproductive-age women showed marked regional and age-specific disparities (Figures 4, 5, and S4, Tables S2 and S6–S9). Sub-Saharan Africa had the most significant increases, especially among 15–19-year-olds, with incidence rising by 205% in the west and 194% in the center (ASR +12%–13%; EAPC: 0.35–0.44). In contrast, High-Income Asia Pacific saw a 45% decline in incidence, and High-Income North America experienced an 11% rise in cases but a 7% drop in ASR (EAPC: –0.50). Prevalence rose in Western Sub-Saharan Africa (+212%) and South Asia (+91%), with milder changes in high-income regions. DALYs followed similar patterns, with major increases in Western Sub-Saharan Africa (+214%) and South Asia (+92%), while high-income areas saw only slight changes. Notably, the 45–49 age group in North Africa and the Middle East showed a 243% increase in DALYs (ASR +17%; EAPC: 0.56), and East Asia showed rising DALY rates despite declining case counts, indicating a growing relative burden.

3.8 | Socio-Demographic Index and Acne Vulgaris Burden Among Women of Reproductive Age: A Global Analysis

The burden of acne among reproductive-age women shows a complex, nonlinear association with the SDI, reflecting the multifaceted link between socioeconomic status and health (Figure S5A–F). Age-standardized incidence (ASIR) and prevalence rates (ASPR) initially decline with rising SDI before increasing again, suggesting a U-shaped relationship (Figure S5A, $R=0.38$, $p=2.6e-28$; Figure S5B, $R=0.33$, $p=2.4e-21$). Western Europe and Central Europe deviate significantly from expectations, with higher and lower burdens, respectively. In contrast, age-standardized DALY rates decrease steadily with increasing SDI (Figure S5C, $R=0.34$, $p=4.8e-22$), though Western Europe still shows elevated burden.

National-level data in 2021 (204 countries) confirm these trends. The ASIR–SDI correlation (Figure S5D, $R=0.42$, $p=2.8e-10$) reveals higher-than-expected burdens in Germany, Portugal, and Norway, while Honduras, Brazil, and Guatemala fall below predicted levels. Similar patterns are found for ASPR (Figure S5E, $R=0.32$, $p=3.3e-06$) and DALY rates (Figure S5F, $R=0.32$, $p=3.0e-06$), with Germany, Portugal, and Luxembourg showing excess burden, and Albania, North Macedonia, and Romania well below expectations.

3.9 | Decomposition Analysis of Changes in Acne Vulgaris Burden Among Women of Reproductive Age From 1990 to 2021

From 1990 to 2021, acne-related DALYs among reproductive-age women increased globally by 515,535 years, primarily driven by population growth (+119.18%), with aging offsetting 42.64% and epidemiological changes adding 23.46% (Figure S6, Table S10).

Similar patterns were observed for prevalence and incidence. High-SDI regions saw modest DALY gains (+10,554.5 years), largely offset by aging (–222.26%). High-middle SDI regions had a net DALY decrease (–10,579.09 years) despite substantial epidemiological growth, due to strong aging effects (–666.3%). DALYs rose substantially in middle-, low-middle-, and low-SDI regions, mainly due to population growth (85%–93%). Regionally, South Asia had the largest DALY rise (+198,612 years), while East Asia (–68,122 years) and High-Income Asia Pacific (–15,462 years) declined due to aging and population reduction. Sub-Saharan Africa showed major DALY increases across all subregions, driven overwhelmingly by population growth (–88%–89%).

3.10 | Health Inequality Analysis of Acne Vulgaris Among Women of Reproductive Age

From 1990 to 2021, health inequalities in acne burden among reproductive age women shifted notably (Figure S7A–F). The SII for incidence dropped from 223 to 103, and the CI declined from 0.09 to 0.04, indicating reduced inequality (Figure S7A,B). In contrast, prevalence showed rising absolute inequality (SII: –319 to 780), though the CI decreased to 0.00, suggesting a more balanced distribution (Figure S7C,D). For DALYs, the SII fell from –6 to –16 and the CI from 0.06 to 0.00 (Figure S7E,F), reflecting a more equitable distribution overall. These findings suggest declining inequality, but with increasingly complex patterns requiring tailored interventions.

3.11 | Projected Global Burden of Acne Vulgaris Among Women of Reproductive Age: 2022–2040

The global burden of acne among reproductive age women is projected to rise steadily through 2040 (Figure S8, Table S11). BAPC model forecasts indicate increases across incidence, prevalence, and DALYs. Incidence is expected to grow from 31.7 million cases in 2022 (ASIR: 1661.01 per 100,000) to 34.9 million in 2040 (ASIR: 1697.54; Figure S8A,B). Prevalence will rise from 91.6 million (ASPR: 4824.41) to 105.3 million (ASPR: 5162.15; Figure S8C,D). DALYs are projected to increase from 1.94 million (rate: 102.30) to 2.21 million (rate: 108.11; Figure S8E,F). Although age-standardized rates show modest growth, the absolute burden will climb substantially due to population expansion and aging, emphasizing the urgent need for strengthened global acne prevention and management strategies.

4 | Discussion

Acne vulgaris (AV) among women of reproductive age has significantly increased globally, with incidence rising by 34%, prevalence by 38%, and disability-adjusted life years (DALYs) by 37% over 32 years. This increase reflects shifts in diet, lifestyle, environmental exposures, and healthcare access, beyond demographic changes alone. The consistent rise in age-standardized rates (ASRs) suggests evolving risk factors are driving this trend. Acne's substantial psychosocial impact, including depression and anxiety, underscores its importance as a public health issue [14, 15]. Environmental pollutants, particularly particulate

matter and nitrogen oxides, have emerged as critical factors exacerbating acne [4, 16].

Disparities in acne burden reflect differences in economic status, healthcare access, and cultural factors. Low- and lower-middle SDI regions experienced dramatic increases in acne incidence (180%), driven by rapid population growth and limited healthcare infrastructure. High-SDI regions maintained stable ASRs due to better diagnostic capabilities, but still face significant disease burdens. Middle-SDI regions show variable trends influenced by urbanization and dietary shifts, highlighting the need for targeted research and intervention [17]. Women aged 15–19 experience the highest acne burden due to hormonal changes and psychosocial impacts, including mental health challenges [18]. Notably, the increasing burden among women aged 45–49 highlights a shift away from acne as primarily adolescent-related, likely driven by hormonal transitions and environmental factors. Older women's experiences include significant stigma and quality-of-life impacts distinct from younger populations, emphasizing the need for tailored management strategies [7, 8].

The trends observed in this study highlight the need for a deeper understanding of the multifactorial etiology of acne. Dietary transitions to high glycemic-load foods and increased dairy consumption have been linked to worsened acne outcomes [19, 20]. Recent evidence specifically implicates the consumption of milk, sugary beverages, and fatty and sugary products with current acne in adults, with an energy-dense dietary pattern showing a significant association with acne symptoms [5, 21], and may explain the rising prevalence in urbanized settings. Environmental pollutants and endocrine disruptors increase oxidative stress and inflammation, worsening acne in industrializing regions [22]. Additionally, urban-related psychological stress may elevate cortisol and sebaceous activity, further contributing to acne development [1, 23].

Climate change, notably rising temperatures and ultraviolet (UV) exposure, further disrupts the skin microbiome and inflammatory responses, contributing to the global acne burden [3, 24].

Addressing the global acne burden requires expanding access to affordable dermatological care, especially in low- and middle-income regions, and promoting health literacy campaigns to encourage early intervention and dietary changes to reduce inflammation. Tailored strategies for different age groups, including mental health support for adolescents and comprehensive care for adults dealing with hormonal and environmental factors, are essential. Enhanced research investment into acne's pathophysiology and environmental influences is necessary for preventive strategies. Integrating acne care into primary healthcare through task-shifting approaches will bolster healthcare systems, while environmental and dietary policy reforms aimed at reducing pollution and fostering healthier lifestyles can significantly mitigate the global burden of acne [25].

According to future projections from 2022 to 2040, the acne burden is expected to increase by 15%, primarily due to population growth and aging, posing significant challenges, especially for low-SDI regions. Strengthening dermatological infrastructure, community interventions, and regional capacity-building in

Sub-Saharan Africa and South Asia is critical. Interdisciplinary research into pollution, dietary changes, and climate impacts is necessary to inform effective preventive and management strategies [3, 21].

5 | Limitation

This study benefits from comprehensive data, wide geographic coverage, and advanced modeling, offering a detailed view of acne vulgaris trends. However, limitations include regional variability in data quality and diagnostic practices, which may lead to underestimation in low-resource settings. Differences in data collection methods may also introduce bias. Additionally, projection models, despite their sophistication, carry inherent uncertainty, particularly regarding future changes in the environment, healthcare access, and diagnostic or treatment practices.

6 | Conclusions

This study analyzed global acne burden trends among women of reproductive age from 1990 to 2021, with projections through 2040. Results indicated significant increases, especially in low-SDI regions like Sub-Saharan Africa and South Asia, while high-SDI regions experienced modest changes. The 15–19 age group had the highest burden, but older groups showed notable growth. Population growth primarily drove burden increases, partially offset by aging populations. Although health inequality generally declined, distribution patterns became more complex. The ongoing rise in acne burden emphasizes the need for targeted prevention strategies, especially in low-SDI regions and younger populations. These findings guide policy and resource allocation, aiming to improve women's health and quality of life globally.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data used for the analyses in the study are publicly available at <https://ghdx.healthdata.org/gbd-2021>.

References

1. S. M. Tuchayi, E. Makrantonaki, R. Ganceviciene, C. Dessinioti, S. R. Feldman, and C. C. Zouboulis, "Acne Vulgaris," *Nature Reviews Disease Primers* 1 (2015): 15029.
2. N. F. Agamia, D. M. Abdallah, O. Sorour, B. Mourad, and D. N. Younan, "Skin Expression of Mammalian Target of Rapamycin and Forkhead Box Transcription Factor O1, and Serum Insulin-Like Growth Factor-1 in Patients With Acne Vulgaris and Their Relationship With Diet," *British Journal of Dermatology* 174 (2016): 1299–1307.
3. A. Belzer and E. R. Parker, "Climate Change, Skin Health, and Dermatologic Disease: A Guide for the Dermatologist," *American Journal of Clinical Dermatology* 24 (2023): 577–593.
4. X. Gu, Z. Li, and J. Su, "Air Pollution and Skin Diseases: A Comprehensive Evaluation of the Associated Mechanism," *Ecotoxicology and Environmental Safety* 278 (2024): 116429.

5. I. Rygula, W. Pikiewicz, and K. Kaminiów, "Impact of Diet and Nutrition in Patients With Acne Vulgaris," *Nutrients* 16 (2024): 1476.
6. V. Kodra, E. Shehu, and A. Xhaja, "Self-Esteem and Mental Health in Adolescents With Acne Vulgaris," *European Neuropsychopharmacology* 28 (2018): S44–S45.
7. Z. Zhu, X. Zhong, Z. Luo, et al., "Global, Regional and National Burdens of Acne Vulgaris in Adolescents and Young Adults Aged 10–24 Years From 1990 to 2021: A Trend Analysis," *British Journal of Dermatology* 192, no. 2 (2024): 228–237, <https://doi.org/10.1093/bjd/ljae352>.
8. S. Gold, M. Siira, S. Willner, et al., "Lived Experience of Acne and Acne Treatment in Transgender Patients," *JAMA Dermatology* 160 (2024): 164–171.
9. A. C. Perkins, J. Maglione, G. G. Hillebrand, K. Miyamoto, and A. B. Kimball, "Acne Vulgaris in Women: Prevalence Across the Life Span," *Journal of Women's Health* 21 (2012): 223–230.
10. GBD 2021 Diseases and Injuries Collaborators, "Global Incidence, Prevalence, Years Lived With Disability (YLDs), Disability-Adjusted Life-Years (DALYs), and Healthy Life Expectancy (HALE) for 371 Diseases and Injuries in 204 Countries and Territories and 811 Subnational Locations, 1990–2021: A Systematic Analysis for the Global Burden of Disease Study 2021," *Lancet* 403 (2024): 2133–2161.
11. GBD 2021 Forecasting Collaborators, "Burden of Disease Scenarios for 204 Countries and Territories, 2022–2050: A Forecasting Analysis for the Global Burden of Disease Study 2021," *Lancet* 403 (2024): 2204–2256.
12. GBD 2021 Demographics Collaborators, "Global Age-Sex-Specific Mortality, Life Expectancy, and Population Estimates in 204 Countries and Territories and 811 Subnational Locations, 1950–2021, and the Impact of the COVID-19 Pandemic: A Comprehensive Demographic Analysis for the Global Burden of Disease Study 2021," *Lancet* 403 (2024): 1989–2056.
13. GBD 2021 Causes of Death Collaborators, "Global Burden of 288 Causes of Death and Life Expectancy Decomposition in 204 Countries and Territories and 811 Subnational Locations, 1990–2021: A Systematic Analysis for the Global Burden of Disease Study 2021," *Lancet* 403 (2024): 2100–2132.
14. D. V. Samuels, R. Rosenthal, R. Lin, S. Chaudhari, and M. N. Nat-suaki, "Acne Vulgaris and Risk of Depression and Anxiety: A Meta-Analytic Review," *Journal of the American Academy of Dermatology* 83 (2020): 532–541.
15. A. M. Layton, D. Thiboutot, and J. Tan, "Reviewing the Global Burden of Acne: How Could We Improve Care to Reduce the Burden?," *British Journal of Dermatology* 184 (2021): 219–225.
16. W. C. A. M. Witkam, E. Essers, S. Petricola, et al., "Association Between Air Pollutant Exposure and Acne Severity in an Adolescent Cohort in The Netherlands," *Journal of the European Academy of Dermatology and Venereology* jdv.20571 (2025), <https://doi.org/10.1111/jdv.20571>.
17. A. H. S. Heng and F. T. Chew, "Systematic Review of the Epidemiology of Acne Vulgaris," *Scientific Reports* 10 (2020): 5754.
18. J. S. Barbieri, "A New Class of Topical Acne Treatment Addressing the Hormonal Pathogenesis of Acne," *JAMA Dermatology* 156 (2020): 619–620.
19. B. C. Melnik, "Acne Vulgaris: The Metabolic Syndrome of the Pilosebaceous Follicle," *Clinics in Dermatology* 36 (2018): 29–40.
20. H. Baldwin and J. Tan, "Effects of Diet on Acne and Its Response to Treatment," *American Journal of Clinical Dermatology* 22 (2021): 55–65.
21. L. Penso, M. Touvier, M. Deschasaux, et al., "Association Between Adult Acne and Dietary Behaviors: Findings From the NutriNet-Santé Prospective Cohort Study," *JAMA Dermatology* 156 (2020): 854–862.
22. K. Paik, J.-I. Na, C.-H. Huh, and J.-W. Shin, "Particulate Matter and Its Molecular Effects on Skin: Implications for Various Skin Diseases," *International Journal of Molecular Sciences* 25 (2024): 9888.
23. K. Mizuno, H. Sakaue, K. Kohsaka, H. Takeda, N. Hayashi, and T. Sato, "An Increase in Normetanephrine in Hair Follicles of Acne Lesions Through the Sympatho-Adrenal Medullary System in Acne Patients With Anxiety," *Journal of Dermatology* 48 (2021): 1281–1285.
24. T. Passeron, C. C. Zouboulis, J. Tan, et al., "Adult Skin Acute Stress Responses to Short-Term Environmental and Internal Aggression From Exposome Factors," *Journal of the European Academy of Dermatology and Venereology* 35 (2021): 1963–1975.
25. A. Clark, K. Haas, and R. Sivamani, "Edible Plants and Their Influence on the Gut Microbiome and Acne," *International Journal of Molecular Sciences* 18 (2017): 1070.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.