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Global Epidemiology and Burden of Migraine in Children and Adolescents from 1990 to 2021: Insights from the Global Burden of Disease Study 2021

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Purpose: Migraine is the most disabling neurological disorder in children and adolescents. This study aimed to comprehensively assess the global burden of migraine in children and adolescents.

Methods: Utilizing the latest data from the Global Burden of Disease (GBD) 2021, trends and disparities in incidence, prevalence, and disability-adjusted life years (DALYs) for migraine among children and adolescents were quantified by sex, age, socio-demographic index (SDI), region, and country. Decomposition analysis and frontier analyses were applied to investigate the underlying factors for changes in burden and the potential for future improvements, respectively.

Results: In 2021, there were 36,794,858 new cases, 205,729,235 prevalent cases, and 7,515,775 DALYs caused by migraine in children and adolescents. From 1990 to 2021, age-standardised incidence rates (ASIR), age-standardised prevalence rates (ASPR), and age-standardised rates of DALYs (ASDR) for migraine in children and adolescents have risen, particularly among males, adolescents aged 15–19 years, regions with middle and higher SDI, East Asia, and Norway. Overall, the burden was higher in females than in males. In 2021, adolescents aged 10–14 exhibited the highest ASIR, whereas adolescents aged 15–19 had the highest ASPR and ASDR. The highest ASPR and ASDR were in low-middle SDI regions, while the highest ASIR was in high SDI regions. Tropical Latin America and Brazil had the highest ASRs regionally and nationally, respectively. Population growth and epidemiological changes drove the increase in DALYs. Regions with middle and higher SDIs hold the greatest improvement potential.

Conclusion: The global burden of migraine in children and adolescents has increased substantially, disproportionately affecting females, adolescents aged 15–19 years, and low-middle SDI regions, while the greatest potential for improvement lies in middle and higher SDI regions, especially Brazil. These findings underscore the need for targeted public health policies and interventions tailored to pediatric migraine across diverse settings.

Keywords: migraine, children and adolescents, epidemiology, global burden of disease, socio-demographic index

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Introduction

Migraine is the most prevalent primary headache in children and adolescents. Unlike adult migraine, children and adolescents often present with atypical symptoms and cyclical syndromes, complicating diagnosis and treatment.[1] This results in higher rates of underdiagnosis and inadequate care, particularly in low- and middle-income countries (LMICs).[2] The Global Burden of Disease (GBD) study 2021 highlighted that migraine is the most disabling neurological disorder among children and adolescents, significantly affecting physical and mental health, school performance, and social activities, thus reducing quality of life.[3,4] Furthermore, migraine in children and adolescents usually persists into adulthood, frequently accompanied by psychiatric comorbidities such as anxiety and depression, which impose substantial economic burdens on individuals, families, and society.[5,6] These factors highlight the need for special attention to migraine in children and adolescents.

Migraine affects 1.16 billion individuals globally, ranking first among children and adolescents (< 20 years).[4] The study[7] showed a remarkable increase in the global burden of children and adolescents migraine from 1990 to 2021, with the fastest growth in prevalence and disability-adjusted life years (DALYs). The global average prevalence of migraine in this population is 11%, increasing with age and varying widely by region, socioeconomic, and gender.[8] Regarding regional differences, a meta-analysis[9] showed that prevalence rates were higher in Europe and the Middle East (8.35% and 8.69%, respectively) compared to Asia and the United States (6.70% and 6.58%, respectively). Nevertheless, these estimates may not reflect the true burden, as studies from Africa, South America, and Oceania were significantly underrepresented, particularly lacking data from LMICs. As the Global Campaign against Headache (GCH) and Global School Programme progress, growing evidence has uncovered greater disparities. For instance, Zambia,[10] a low-income country in Africa, and Lithuania,[11] a high-income country in Europe, surveyed people aged 7–17 about headaches, finding that the prevalence of migraine was 53.2% and 21.4%, respectively, which is much higher than the global average. This not only reflected that the burden in LMICs may have been seriously underestimated, but also highlighted the differences in prevalence rates between countries with different socioeconomic levels. Furthermore, lower socioeconomic status is associated with an increased prevalence of migraine, influenced by factors such as poverty, limited access to healthcare services, and rural living environments. Several studies[12] have indicated that females exhibit a higher incidence and prevalence of migraine, particularly after adolescence. These significant differences highlight the urgency of conducting a more comprehensive and representative global epidemiological assessment of migraine in children and adolescents. Although a study[13] outlined the general epidemiology of migraine in children and adolescents using GBD 2021, specific trends and regional, socio-demographic index (SDI), and gender differences remain unclear. Moreover, a lack of analyses of the drivers and frontiers of migraine burden in children and adolescents impedes the development of effective interventions.

To address these gaps, this study aims to summarize and analyze the incidence, prevalence, and DALYs of migraine in children and adolescents from 1990 to 2021, stratified by gender, age groups, and SDI at the global, regional, and national levels. Additionally, Decomposition analysis was employed to identify factors contributing to changes in the burden of migraine in this population. Finally, we assessed potential improvements in migraine burden among children and adolescents to pinpoint countries or regions requiring additional efforts, informing migraine in children and adolescents prevention and management policy development.

Methods

Study Population and Data Collection

Migraine data for children and adolescents in this study were sourced from GBD 2021, which offers a comprehensive and up-to-date analysis of 371 diseases across 204 countries and territories, using recent epidemiological data and improved standardised methods.[14] All countries and territories were classified into 21 regions and grouped into five categories based on the SDI. The 21 regions are composed of countries and territories that are geographically close, epidemiologically similar, and share similar distributions of causes of death. For SDI, it is a composite indicator of background social and economic conditions that influence health outcomes in each location. It is the geometric mean of 0 to 1 indices of total fertility rate for those younger than 25 years old, mean education for those 15 years old and older, and lagdistributed income per capita. In the GBD 2021, SDI values range from 0, representing lowest income and years of schooling, and highest fertility, to 1, indicating highest income and years of schooling, and lowest fertility.[14] Countries and territories are classified into five groups based on their SDI scores: high SDI (> 0.81), high-middle SDI (0.72–0.81), middle SDI (0.63–0.71), low-middle SDI (0.47–0.62) and low SDI (< 0.47). Besides, according to the World Health Organization (WHO) definition, the 0–19 year age group is categorized as children and adolescents. Due to the absence of migraine data for children under 5 years old, the dataset was divided into three age groups: younger children (5–9 years), younger adolescents (10–14 years), and older adolescents (15–19 years).[15]

We extracted data specific to the annual incidence, prevalence, DALYs, and age-standardised rates (ASRs) for migraine in individuals aged 5–19 years globally from the Global Health Data Exchange (https://vizhub.healthdata.org/gbd-results/). For GBD studies, a waiver of informed consent was reviewed and approved by the Institutional Review Board at the University of Washington. Additionally, according to Article 32, Items 1 and 2 of the Measures for Ethical Review of Life Science and Medical Research Involving Human Subjects promulgated by the National Health Commission of the People's Republic of China on 18 February 2023, in which "research using legally obtained public data or anonymised information data" is exempt from ethical review. This study relied on anonymised public data from the GBD database, which qualified for exemption from ethical review without ethical approval from an institutional review board.

Statistical Analysis

The methodologies used by Health Metrics and Evaluation for the GBD 2021 Study, along with key improvements over previous cycles, are detailed in earlier studies.[14,16] In this study, a 95% uncertainty interval (UI) for each variable was determined using the 2.5th and 97.5th percentiles of the posterior distribution from 1000 draw values. For ease of comparison, all rates are presented per 100,000 population. All tests were two-sided, with $P < 0.05$ considered statistically significant. Incidence and prevalence were modeled using the Bayesian Disease Modelling Meta-Regression tool (version 2.1). DALYs, a comprehensive measure of disease burden, were calculated as the sum of years of life lost and years lived with disability. We also analyzed age-adjusted rates of disease incidence, prevalence, and DALYs globally, regionally, and nationally, disaggregated by age, sex, and SDI.

Joinpoint regression analysis was performed to assess trends in migraine burden among children and adolescents using Joint Command Line Version. This tool tracks temporal trends in data and fits the simplest model by connecting multiple line segments on a logarithmic scale. Average annual percentage changes (AAPCs) were calculated to evaluate trends. AAPC represents a geometrically weighted average of annual percentage changes from the joinpoint analysis, with weights proportional to the length of each period within the specified time interval.[17] The 95% confidence interval (CI) was derived from the linear regression model. An AAPC value and 95% CI greater than zero indicate an increasing trend in ASR, and vice versa.

We applied the decomposition methods developed by Das Gupta to illustrate the contributions of three factors-aging, population, and epidemiology-to changes in DALYs between 1990 and 2021.[16] Moreover, nonparametric data envelopment analysis was employed, drawing on previous studies to construct a nonlinear frontier.[18] This frontier represents the lowest achievable burden based on development status. Detailed methodologies for decomposition and frontier analysis are provided in the Supplementary methods. All statistical analyses and visualizations were conducted using R version 4.3.2.

Results

Global Trends

Globally, there were 30,159,793 (95% UI, 20,388,195 to 41,772,246) new cases of migraine among children and adolescents in 1990 compared to 36,794,858 (95% UI, 24,894,467 to 50,875,831) new cases in 2021, reflecting a 22% increase. During the same period, the number of prevalent cases increased from 165,687,028 (95% UI, 122,901,784 to 215,760,524) to 205,729,235 (95% UI, 152,945,712 to 268,680,883), a 24.17% increase. Moreover, DALYs associated with migraine in children and adolescents increased from 6,042,776 (95% UI, 395,006 to 15,051,635) to 7,515,775 (95% UI, 484,365 to 18,769,692), a 24.38% rise (Table 1).

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Table 1 The Global Incidence, Prevalence, and Disability-Adjusted Life-years of Migraine in Children and Adolescents for Both Sexes and All SDI, with AAPC From 1990 and 2021

Variables	Location	1990		2021		AAPC % (95% CI) 1990–2021	P value
		Cases (95% UI)	ASR (per 100, 000) (95% UI)	Cases (95% UI)	ASR (per 100, 000) (95% UI)		
Incidence	Global	30,159,792.8 (20,388,195.2 to 41,772,246.04)	1845.92 (1249.97 to 2553.58)	36,794,857.75 (24,894,466.96 to 50,875,831.48)	1858.23 (1257.53 to 2569.01)	0.02 (0.01 to 0.04)	0.007
	Female	18,553,002.62 (12,513,712.42 to 25,696,818.29)	2324.2 (1570.78 to 3214.81)	22,153,360.57 (14,956,229.88 to 30,700,208.9)	2307.78 (1558.63 to 3197.24)	−0.02 (−0.04 to −0.01)	0.004
	Male	11,606,790.18 (7,824,667.15 to 16,224,415.83)	1389.15 (937.78 to 1939.74)	14,641,497.17 (9,908,506.67 to 20,380,319.23)	1435.12 (971.37 to 1997.74)	0.11 (0.09 to 0.14)	< 0.001
	High SDI	3,817,496.33 (25,26,126.75 to 5,379,769.8)	2006.6 (1332.26 to 2819.7)	3,742,835.92 (2,479,098.88 to 5,280,870.09)	2075.7 (1376.65 to 2925.56)	0.1 (0.07 to 0.13)	< 0.001
	High-middle SDI	4,519,369.6 (3,014,993.86 to 6,326,292.67)	1628.62 (1090.82 to 2271.87)	3,929,414.88 (2,625,896.45 to 5,478,636.24)	1681.57 (1123.67 to 2344.71)	0.1 (0.09 to 0.12)	< 0.001
	Middle SDI	10,300,212.51 (7,046,210.81 to 14,177,842.48)	1835.9 (1259.92 to 2521.25)	10,832,364.58 (7,384,331.94 to 14,883,378.81)	1890.3 (1289.24 to 2596.33)	0.09 (0.06 to 0.12)	< 0.001
	Low-middle SDI	8,382,771.31 (5,700,884.44 to 11,554,306.41)	2003.52 (1359.6 to 2764.74)	11,368,438.93 (7,751,647.9 to 15,673,846.2)	1985.74 (1355.16 to 2736.35)	−0.02 (−0.04 to 0)	0.036
	Low SDI	3,112,432.76 (2,069,445.27 to 4,336,656.22)	1649.27 (1093.45 to 2302.44)	6,893,720.79 (4,594,843.48 to 9,644,385.96)	1644.21 (1094.19 to 2302.67)	0 (−0.02 to 0.01)	0.592
	5-9	9,375,143.98 (6,194,247.06 to 13,204,226.11)	1606.62 (1061.51 to 2262.82)	11,080,972.2 (7,322,452.25 to 15,592,669.65)	1612.83 (1065.78 to 2269.5)	0.02 (−0.04 to 0.07)	0.579
	10-14	12,579,737.43 (9,292,347.8 to 16,268,002.64)	2348.36 (1734.67 to 3036.87)	15,792,114.03 (11,721,389.92 to 20,366,947.71)	2368.93 (1758.29 to 3055.18)	0.03 (0.01 to 0.05)	0.002
	15-19	8,204,911.4 (4,901,600.35 to 12,300,017.29)	1579.62 (943.66 to 2368.01)	9,921,771.52 (5,850,624.79 to 14,916,214.13)	1590.08 (937.63 to 2390.5)	0.03 (0.01 to 0.05)	0.013
Prevalence	Global	165,687,027.67 (122,901,783.75 to 215,760,523.99)	10,042.66 (7447.84 to 13,085.15)	205,729,235.05 (152,945,711.93 to 268,680,883.25)	10,255.74 (7620.86 to 13,399.98)	0.07 (0.06 to 0.09)	< 0.001
	Female	102,481,588.13 (76,171,916.89 to 132,832,469.42)	12,678.52 (9420.59 to 16,444.11)	124,450,759.27 (92,766,116.45 to 162,153,866.44)	12,777.96 (9519.41 to 16,657.93)	0.03 (0.01 to 0.05)	< 0.001
	Male	63,205,439.54 (46,580,138.73 to 82,773,586.68)	7511.24 (5535.28 to 9841.08)	81,278,475.78 (59,719,954.92 to 106,289,330.17)	7875.49 (5784.64 to 10,302.96)	0.16 (0.14 to 0.18)	< 0.001
	High SDI	20,989,284.48 (15,379,158.02 to 27,306,405.03)	10,550.51 (7725.02 to 13,763.44)	20,333,340.38 (14,980,993.54 to 26,631,114.18)	10,868.58 (7999.3 to 14,259.27)	0.09 (0.06 to 0.12)	< 0.001
	High-middle SDI	25,442,258.98 (18,824,058.34 to 33,205,630.83)	8731.52 (6451.44 to 11,423.78)	21,424,548.47 (15,756,493.27 to 28,033,166.14)	9122.65 (6707.77 to 11,938.76)	0.13 (0.09 to 0.16)	< 0.001
	Middle SDI	57,766,062.61 (42,996,541.88 to 74,989,571.41)	9987.65 (7428.99 to 12,979.45)	61,363,187.54 (45,686,747.76 to 79,772,520.57)	10,520.21 (7828.39 to 13,683.67)	0.18 (0.15 to 0.21)	< 0.001
	Low-middle SDI	45,182,842.93 (33,317,415.54 to 59,258,548.91)	11,200.65 (8267.89 to 14,669.07)	65,004,285.02 (48,392,547.78 to 84,971,164.85)	11,085.09 (8246.48 to 14,501.39)	−0.03 (−0.05 to 0)	0.028
	Low SDI	16,150,739.1 (11,739,089.35 to 21,465,258.21)	9097.9 (6628.6 to 12,059.65)	37,444,401.85 (27,312,720.78 to 49,847,283.5)	9066.89 (6616.38 to 12,061.4)	−0.01 (−0.03 to 0.01)	0.377
	5-9	14,767,041.23 (9,823,783.66 to 20,585,697.12)	2530.64 (1683.51 to 3527.78)	17,455,195.54 (11,640,912.01 to 24,478,806.8)	2540.59 (1694.32 to 3,562.87)	0.02 (−0.04 to 0.07)	0.571
	10-14	63,492,597.52 (47,413,936.62 to 84,121,631.43)	11,852.65 (8,851.12 to 15,703.63)	79,974,614.55 (59,777,743.44 to 106,050,718.12)	11,996.74 (8,967.07 to 15,908.34)	0.04 (0.01 to 0.06)	0.010
	15-19	87,427,388.92 (65,664,063.48 to 111,053,195.43)	16,831.62 (12,641.72 to 21,380.09)	108,299,424.96 (81,527,056.48 to 138,151,358.33)	17,356.24 (13,065.65 to 22,140.35)	0.11 (0.09 to 0.13)	< 0.001

Disability-adjusted life-years	Global	6,042,775.97 (395,006.19 to 15,051,635.05)	366.11 (23.73 to 912.43)	7,515,775.31 (484,365.23 to 18,769,692.03)	374.5 (24.02 to 935.71)	0.08 (0.06 to 0.11)	< 0.001
	Female	3,730,180.65 (228,114.17 to 9,355,305.4)	461.26 (27.92 to 1157.49)	4,535,468.2 (279,486.75 to 11,350,078.29)	465.46 (28.51 to 1165.44)	0.02 (−0.01 to 0.04)	0.130
	Male	2,312,595.32 (165,891.3 to 5,710,487.72)	274.71 (19.58 to 678.71)	2,980,307.11 (203,055.12 to 7,380,618.78)	288.65 (19.59 to 715.2)	0.17 (0.14 to 0.2)	< 0.001
	High SDI	757,485.09 (52,659.84 to 1,855,355.3)	380.16 (25.75 to 934.35)	732,009.88 (49,039.73 to 1,788,214.39)	390.82 (25.73 to 957.63)	0.08 (0.04 to 0.12)	< 0.001
	High-middle SDI	940,958.87 (78,279.76 to 2,276,674.59)	322.21 (26.07 to 782.56)	792,547.94 (61,452.38 to 1,946,891.06)	337.41 (26.12 to 829.05)	0.14 (0.1 to 0.18)	< 0.001
	Middle SDI	2,126,579.39 (132,719 to 5,330,829.83)	367.26 (22.47 to 921.62)	2,260,066.96 (137,304.2 to 5,687,767.1)	387.25 (23.36 to 975)	0.18 (0.15 to 0.22)	< 0.001
	Low-middle SDI	1,632,620.9 (89,542.63 to 4,099,643)	405.27 (22.65 to 1015.99)	2,367,329.51 (136,646.2 to 5,901,590.28)	403.37 (23.05 to 1006.33)	−0.01 (−0.04 to 0.02)	0.620
	Low SDI	579,429.77 (41,130.04 to 1,431,541.74)	327.33 (23.94 to 805.01)	1,357,954.94 (99,197.12 to 3,358,735.73)	329.07 (24.27 to 813.13)	0.03 (0 to 0.06)	0.071
	5-9	492,448.45 (10,460.27 to 1,374,370.9)	84.39 (1.79 to 235.53)	584,845.33 (13,180.58 to 1,607,282.64)	85.12 (1.92 to 233.94)	0.04 (0 to 0.07)	0.049
	10-14	2,297,212.25 (100,959.27 to 5,782,523.33)	428.84 (18.85 to 1079.47)	2,897,557.37 (125,710.61 to 7,274,035.55)	434.65 (18.86 to 1091.16)	0.04 (0.02 to 0.06)	< 0.001
	15-19	3,253,115.27 (283,586.66 to 7,894,740.82)	626.29 (54.6 to 1519.9)	4,033,372.61 (345,474.04 to 9,888,373.84)	646.39 (55.37 to 1,584.73)	0.11 (0.09 to 0.14)	< 0.001

Abbreviations: AAPC, Average annual percentage change; ASR, Age-standardised rate; CI, Confidence interval; UI, Uncertainty interval; SDI, Socio-demographic index.

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Regarding ASR, the age-standardised incidence rate (ASIR), age-standardised prevalence rate (ASPR), and age-standardised DALY rate (ASDR) of migraine in children and adolescents were 1,858.23, 10,255.74, and 374.5 per 100,000 population in 2021, respectively, with an increasing trend over the past 32 years. Specifically, as shown in Figure 1, the ASIR significantly increased between 1999 and 2008 (APC = 0.24% [95% CI, 0.21 to 0.28], $P < 0.05$), while it decreased slightly in 1990–1999 (APC = −0.1% [95% CI, −0.13 to −0.07], $P < 0.05$) and 2008–2021 (APC = −0.05% [95% CI, −0.07 to −0.03], $P < 0.05$), respectively. The ASPR and ASDR exhibited significant increases in 1990–1994 and 2002–2010 (ASPR: APC = 0.3% [95% CI, 0.27 to 0.34], $P < 0.05$; ASDR: APC = 0.31% [95% CI, 0.26 to 0.36], $P < 0.05$), with decreases observed in 1994–2002 and 2010–2021 (ASPR: APC = −0.05% [95% CI, −0.06 to −0.03], $P < 0.05$; ASDR: APC = −0.04% [95% CI, −0.07 to −0.02], $P < 0.05$).

Global Trends by Sex and Age Group

In 2021, the number and ASR of migraine incidence, prevalence, and DALYs were higher in female children and adolescents than in males (Table 1). This sex difference persisted across all regions, SDIs, and age groups (Supplementary Tables S1–S5). However, from 1990 to 2021, the ASIR, ASPR, and ASDR of migraine in male children and adolescents increased faster than in females (Table 1).

By age groups, the highest incidence of cases and ASR occurred in the 10–14 age group in 2021, while the prevalence and DALYs were highest in the 15–19 age group. Moreover, the burden increased in all age groups from 1990 to 2021, with the fastest growth among adolescents aged 15–19 (Table 1).

Global Trends by SDI

From 1990 to 2021, the burden of migraine among children and adolescents varied significantly across different SDI regions (Table 1 and Figure 2). In 2021, low-middle SDI countries reported the highest number of incidence (11,368,439; 95% UI, 7,751,648 to 15,673,846), prevalence (65,004,285; 95% UI, 392,548 to 84,971,165), and DALYs (2,367,330; 95% UI, 136,646 to 5,901,590). These regions also had the highest ASPR (11085.09; 95% UI, 8246.48 to 14501.39/100,000) and ASDR (403.37; 95% UI, 23.05 to 1006.33/100,000), while high SDI regions had the highest ASIR (2075.7; 95% UI, 1376.65 to 2925.56/100,000).

Over the past 32 years, all ASRs in the middle and higher SDI regions show an upward trend, while the low-middle and low SDI regions have remained stable or slightly declined (Table 1 and Figure 2).

Regional Trends

For details on regional burden trends are presented in Supplementary Tables S3–S5. In 2021, South Asia reported the highest number of migraine cases in children and adolescents, with 10,311,023 new cases (95% UI, 6,982,859 to 14,226,753), 59,338,336 prevalent cases (95% UI, 44,447,336 to 77,409,866), and 2,128,744 DALYs (95% UI, 116,421 to 5,268,538). In contrast, Tropical Latin America had the highest ASIR (3262.2; 95% UI, 2404.36 to 4298.24/100,000), ASPR (20,190.52; 95% UI, 15,753.44 to 25,680.25/100,000), and ASDR (740.98; 95% UI, 22.78 to 1853.05/100,000).

Since 1990, Eastern Asia has experienced the greatest growth in all ASRs across 21 regions, with AAPCs of 0.21 for ASIR (95% CI, 0.15 to 0.28), ASPR (95% CI, 0.16 to 0.27), and ASDR (95% CI, 0.16 to 0.27), while high-income North America suffered the fastest decrease, with AAPCs of −0.06 for ASIR (95% CI, −0.12 to 0), −0.13 for ASPR (95% CI, −0.2 to −0.05), and −0.16 for ASDR (95% CI, −0.26 to −0.07).

National Trends

In 2021, India had the most cases of incidence (7,647,830; 95% UI, 5,197,424 to 10,531,552), prevalence (44,452,954; 95% UI, 33,453,806 to 58,055,511), and DALYs (596,331; 95% UI, 91,949 to 3,936,816) globally (Supplementary Table S6). In terms of ASR, Brazil had the highest ASIR (3267.32; 95% UI, 2405.3 to 4299.35/100,000), ASPR (20,220.58; 95% UI, 15,794.05 to 25,697.68/100,000), and ASDR (741.92; 95% UI, 22.79 to 1856.69/100,000), while Ethiopia had the lowest ASRs (Figures 3, 4 and Supplementary Table S6).

Over the past 32 years, Norway saw the largest increase in all ASRs for migraine in children and adolescents among 204 nations (ASIR: AAPC = 0.51 [95% CI, 0.38 to 0.65]; ASPR: AAPC = 0.6 [95% CI, 0.42 to 0.78]; ASDR: AAPC =

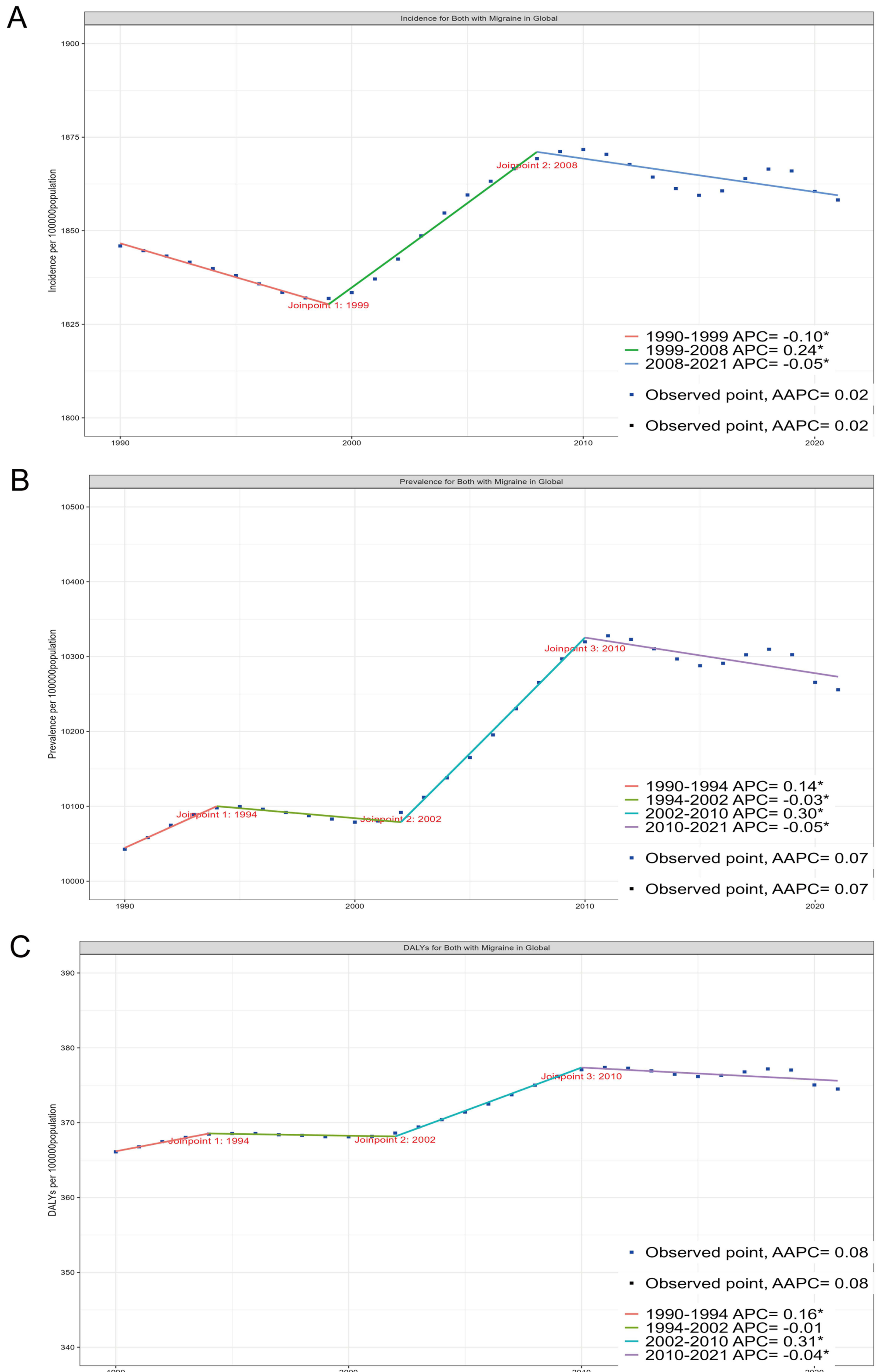

Figure 1 Global trends for age-standardised rates (per 100,000 population) of migraine in children and adolescents from 1990 to 2021, calculated by Joinpoint regression. (**A**) Age-standardised incidence rate; (**B**) age-standardised prevalence rate; (**C**) age-standardised DALYs rate.

Notes: The Joinpoint is the turning point where a trend undergoes a significant change, dividing the overall trend into distinct time periods (represented in the figure by broken lines of different colours). AAPC represents the average annual percentage change from 1990 to 2021, reflecting the overall average trend, while APC refers to the annual percentage change across different time periods, indicating trend variations within each interval. AAPC and APC values above zero indicate an upward trend, and vice versa, **P* < 0.05.

Abbreviations: AAPC, Average annual percentage change; APC, Annual percentage change; DALYs, Disability-adjusted life-years.

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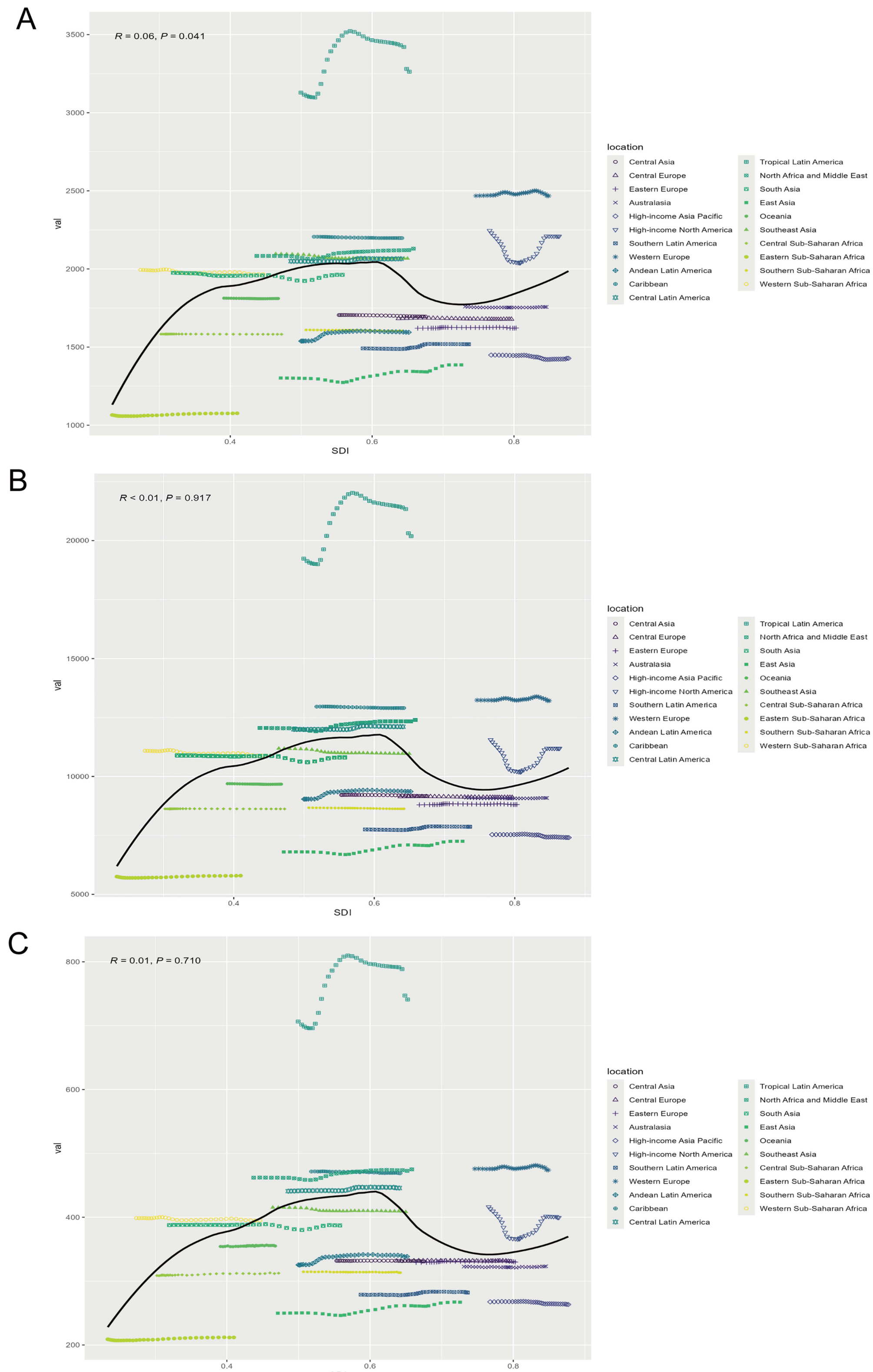

Figure 2 Association between ASRs (per 100,000 population) of migraine in children and adolescents and SDI among 21 regions from 1990 to 2021. (**A**) Age-standardised incidence rate; (**B**) age-standardised prevalence rate; (**C**) age-standardised DALYs rate.

Notes: The symbols of varying colours and shapes in the figure represent 21 regions. For each region, the dots from left to right depict the estimated values for each year from 1990 to 2021. The black line represents the expectation ASR based on SDI. The Pearson correlation coefficient R represents the strength of association between the SDI and the ASRs of migraine burden among children and adolescents. An R value greater than 0 indicates a positive correlation between the two variables, and vice versa. The p-value is adjusted following Bonferroni correction, with statistical significance defined as $p < 0.05$.

Abbreviations: ASRs, Age-standardised rates; SDI, Socio-demographic index; DALYs, Disability-adjusted life-years.

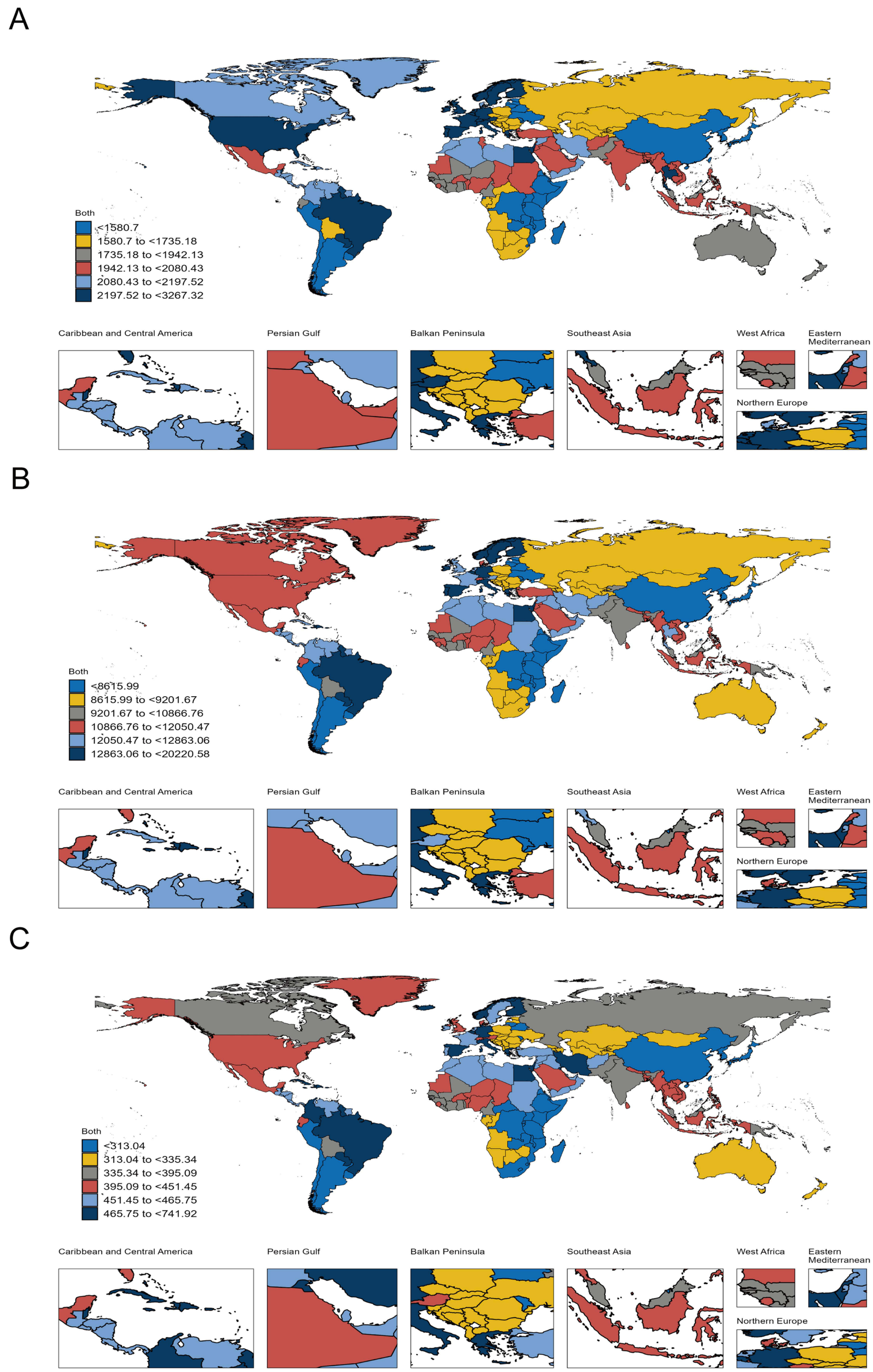

Figure 3 World maps depicting the ASRs (per 100,000 population) of migraine in children and adolescents in 2021. (**A**) Age-standardised incidence rate; (**B**) age-standardised prevalence rate; (**C**) age-standardised DALYs rate.

Notes: We employed a quantile method (six-category classification) to divide the ASRs for 204 countries and regions in 2021 into six numerical intervals. The blue, yellow, grey, red, light blue and dark blue colours in the figure represent six numerical intervals in ascending order, for example: blue indicates a lower numerical range, whilst dark blue indicates a higher numerical range. As can be seen from Figure 3A, Ethiopia and Somalia in sub-Saharan Africa, as well as South Korea and China in East Asia, are coloured blue, indicating lower age-standardised incidence rates (<1580.7). Conversely, Brazil in Latin America and the United States in North America are coloured dark blue, signifying higher age-standardised incidence rates (within the range of 2197.52 to <3267.32). The original data were obtained from the GBD studies. Although there may be problems in regional division, this was not the key point for this study.

Abbreviations: ASRs, Age-standardised rates; DALYs, Disability-adjusted life-years.

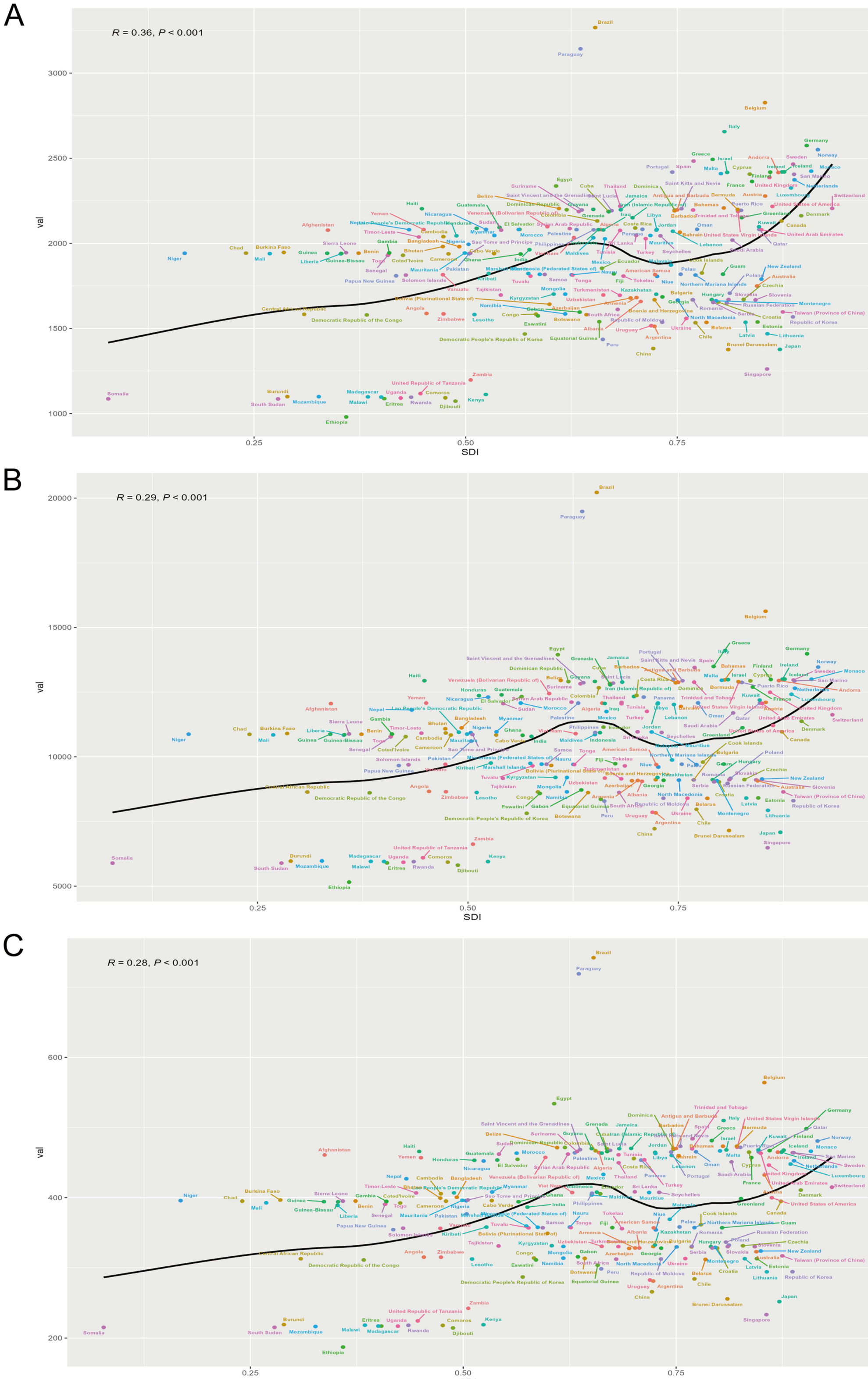

Figure 4 The ASRs (per 100,000 population) of migraine in children and adolescents among 204 countries and territories by SDI in 2021. (**A**) Age-standardised prevalence rate; (**B**) age-standardised incidence rate; (**C**) age-standardised DALYs rate.

Notes: The dots of different colours in the figure represent 204 countries and territories respectively. The R value represents the Pearson correlation analysis between SDI and ASR. An R value greater than zero indicates a positive correlation between the two variables, and vice versa. P-values were adjusted using the Bonferroni correction, with statistical significance defined as $P < 0.05$.

Abbreviations: ASRs, Age-standardised rates; SDI, Socio-demographic index; DALYs, Disability-adjusted life-years.

0.58 [95% CI, 0.4 to 0.77]), while Thailand experienced the largest decrease (ASIR: AAPC = −0.24 [95% CI, −0.25 to −0.23]; ASPR: AAPC = −0.29 [95% CI, −0.31 to −0.27]; ASDR: AAPC = −0.29 [95% CI, −0.34 to −0.24], Supplementary Table S6).

Decomposition Analysis

Globally, population growth, epidemiologic changes, and population aging accounted for 86.17%, 10.49%, and 3.34% of the increase in DALY (Supplementary Table S7). Figure 5 presents population growth as the primary driver for the burden of DALYs in the low- (93.19%), low-middle- (84.99%), and middle- (24.74%) SDI, while acting as a negative factor in high- (−170.34%) and high-middle- (−100.58%) SDI. Epidemiologic changes played a significant role in the total DALYs change in middle- (88.36%) and high- (82.08%) SDI, whereas they had a weaker impact in high-middle (27.12%) and a negative effect in low-middle SDI (−1.27%). Furthermore, population aging contributed positively to DALY changes in low- (6.17%) and low-middle SDI regions (16.28%), but negatively in the other three SDI quintiles, with the most pronounced effect in high-middle-SDI regions (−26.54%). Decomposition analysis at regional and national levels revealed substantial disparities in the contributions of these determinants to DALY changes (Supplementary Table S7).

Frontier Analysis

Using data from 1990 to 2021, frontier analysis based on ASDR and SDI was performed to highlight unrealized health benefits across countries or territories at different development levels (Figure 6A). Figure 6B and Supplementary Table S8

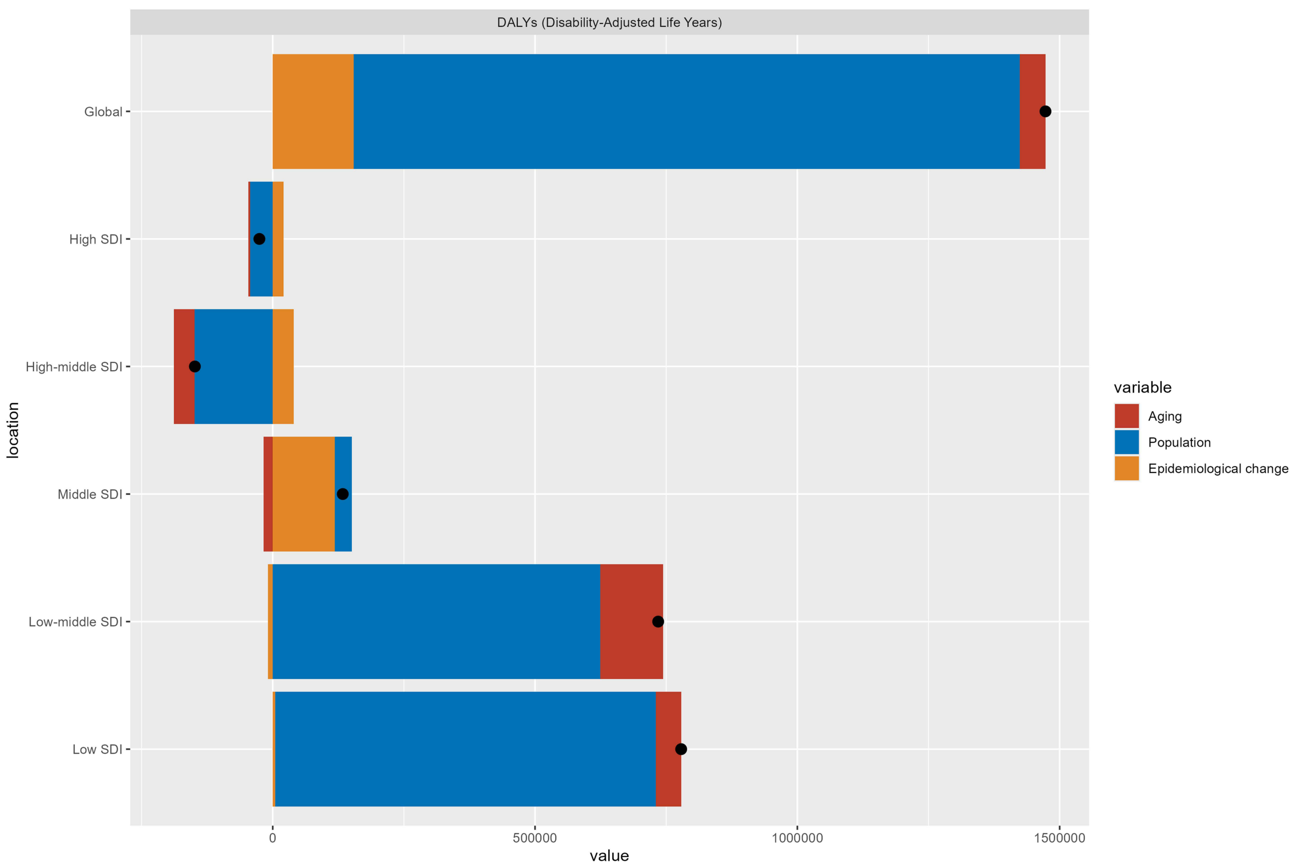

Figure 5 Changes in DALYs of migraine in children and adolescents according to population-level determinants of population growth, aging, and epidemiological change from 1990 to 2021 at the global level and by SDI quintile.
Notes: The red, blue, and orange colours in the figure correspond respectively to the three factors driving changes in DALYs: ageing, population and epidemiological change. For each component, the length of the bar indicates the strength of its contribution. The magnitude of a positive value indicates a corresponding increase in migraine in children and adolescents attributed to the component, while the magnitude of a negative value indicates a corresponding decrease.
Abbreviations: DALYs, Disability-adjusted life years; SDI, Socio-demographic index.

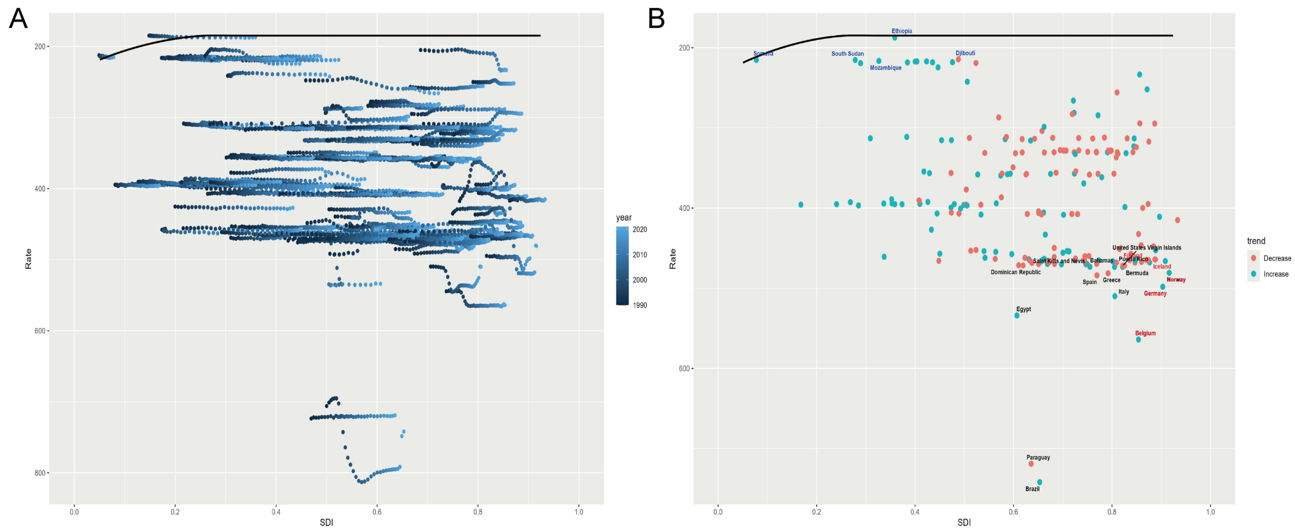

Figure 6 Frontier analysis based on SDI and age-standardised DALYs rate of migraine among children and adolescents from 1990 to 2021.
Notes: The frontier line was delineated in black. Countries and territories were represented as dots. The color scale ranges from dark blue for 1990 to light blue for 2021. (**A**). The green dots indicate an increase in the age-standardised DALYs rate for migraine among children and adolescents from 1990 to 2021, while the red dots show a decrease. (**B**). The top 15 countries with the largest effective difference are highlighted in black. As examples, frontier countries with a lower SDI (< 0.5) and a smaller effective difference are marked in blue, while countries and territories with a higher SDI (> 0.85) and a relatively larger effective difference are marked in red.
Abbreviations: DALYs, Disability-adjusted life years; SDI, Socio-demographic index.

show the effective differences in 2021 among countries with varying SDI levels, revealing an inverted triangular relationship. Countries with low-middle, middle, and high-middle SDI generally exhibited higher effective differences, whereas those with very low or very high SDI showed lower differences. Specifically, Brazil (557.04) and Paraguay (534.11), with middle SDI quintiles, were the top two countries with the greatest chance to narrow the gap. However, leading performances were not limited to high SDI countries; some low SDI countries, such as Ethiopia (2.3) and Somalia (2.43), were also approaching the frontier. Similarly, several high-SDI countries, including Belgium (379.13), Italy (325.05), and Germany (313.29), had disappointingly high effective differences.

Discussion

To our knowledge, this study represents the most thorough analysis of the migraine burden in children and adolescents currently available using GBD 2021 data, revealing the fluctuating upward trend from 1990 to 2021, with significant differences across SDI, region, gender, and age group levels. Our findings indicate that the heaviest burden are observed in low-middle SDI regions, whereas regions with middle and higher SDI are growing faster and have the greatest improvement potential. Notably, adolescents and women bear a higher migraine burden, while the growth rate is more significant in men. These disparities reflect the severe inequalities in the distribution of medical resources and access to care across the globe, possibly driven by geography, politics, and ethnicity factors, emphasizing the need for targeted public health policies and interventions to address this debilitating disease.

Consistent with previous studies,[7,13] our research indicates an overall upward trend of migraine in children and adolescents globally. However, joinpoint regression analysis also reveals a recent decline in all ASRs since 2010. This complex pattern may reflect the interplay between societal development, environmental change, and public health response capacity. For one thing, the rising burden may be attributed to changes in lifestyle and environment brought about by socioeconomic development. Climate change, such as increased humidity, and exposure to traffic pollutants accompanying urbanisation have been linked to migraine attacks.[19] Concurrently, lifestyle factors including sleep deficit, insufficient exercise, unhealthy diet, and excessive screen time are becoming increasingly prevalent among youth and potentially contribute to the epidemic of migraine.[20] Besides, children and adolescents, being in a critical phase of psychological and physiological development, are more susceptible to multiple stressors and comorbidities, such as anxiety and depression, which can interact to increase the frequency of migraine attacks.[21] The social isolation and psychological stress resulting from the coronavirus disease 2019 pandemic may have further exacerbated this trend.[22] For another, the recent downward trend may indicate the positive impact of global public health initiatives. Since 2000, the WHO has prioritised headaches as a public health concern, collaborating with the Lifting The Burden initiative to launch the GCH.[23] The publication of the Atlas of Headache Disorders in 2011 raised awareness globally and advanced methodological standards in epidemiological research.[24] Additionally, organizations such as the International Headache Society and the European Headache Federation, along with countries including China, have integrated headache management education into primary healthcare priorities. These efforts may have improved healthcare access and facilitated the implementation of preventive strategies, thereby attenuating the growth in disease burden to some extent. Future global efforts should focus on establishing consensus guidelines for epidemiological study to better address the public health burden of migraine in children and adolescents.

The burden of migraine in children and adolescents varies significantly across SDI levels, regions, and countries. These disparities are associated not only with geographic and demographic factors, including ethnicity, but are also likely influenced by healthcare resources, epidemiological surveillance capabilities, and the intensity of policy interventions. Low-middle SDI regions have the greatest burden and show a slight downward trend, with Tropical Latin America and South Asia being particularly prominent in terms of all ASRs and case numbers, respectively. Decomposition analysis indicates that population growth is the primary driver of high burdens in this region. Low- and middle-income regions with rapidly growing child and adolescent populations including South Asia, are projected to host the largest concentration of children globally by 2050, posing severe challenges to their healthcare and social service systems.[25,26] Moreover, healthcare resources in these regions have historically been focused on infectious diseases, with comparatively limited attention paid to non-communicable diseases (NCDs) such as migraine.[27] Geographic isolation, political instability, and inadequate diagnostic and treatment capacities further constrain access to pediatric migraine services. In contrast, high SDI regions exhibit the highest ASIR, while middle and higher SDI regions experience accelerated growth in disease burden, particularly in East Asia. This trend aligns with the results of the decomposition analysis, indicating that this increase is driven more by epidemiological changes. These regions have generally established earlier and more systematic research on migraine in children and adolescents. Their continuously refined epidemiological methodologies, stronger healthcare systems, and heightened public health awareness contribute to higher rates of reporting and diagnosis.[28] Whereas in low-SDI regions, despite a greater actual disease burden, diagnostic limitations and insufficient surveillance capacity likely result in substantial underreporting. It is noteworthy that even in high SDI countries such as the United States and Russia, underdiagnosis and inadequate treatment remain widespread. These issues may be linked to inequalities in healthcare accessibility across racial, ethnic, and socioeconomic groups, further illustrating that healthcare equity involves more than national economic wealth.

At the national level, Brazil ranked first across all ASRs in 2021, which may be attributable to factors such as the widespread use of electronic devices, limited healthcare resources, stressful lifestyles, and poor governmental attention.[29] By contrast, Norway, a high SDI country, demonstrated the most substantial increase in all ASRs over time. This trend can be explained, on the one hand, by its role as the academic base for the GCH, which has strongly emphasized headache epidemiological research.[30] On the other hand, it is also linked to the cumbersome referral system and insufficient headache training.[31] Meanwhile, Thailand experienced the most rapid decline in migraine burden, achieved through the implementation of the universal health coverage policy and the community pharmacy management model.[32,33] This practice underscores the critical role of healthcare policies in alleviating disease burdens. Frontier analysis further indicated that countries with middle and higher SDI, particularly Brazil, possess the greatest potential for improvement, suggesting current healthcare resources for migraine prevention and treatment are underutilized. However, low SDI countries, such as Somalia and Ethiopia, show limited potential for improvement, possibly due to severely constrained healthcare resources rather than already achieving better performance.[34] Therefore, it is essential to develop differentiated public health strategies tailored to different SDI levels: low and low-middle SDI countries should prioritise enhancing disease recognition and expanding primary healthcare coverage. This can be achieved through training grassroots healthcare personnel and promoting low-cost non-pharmaceutical interventions. Middle and higher SDI countries, meanwhile, should focus on enhancing service efficiency by establishing clinical guidelines, developing tiered healthcare systems, and implementing multidisciplinary collaborative models for headache management.[35,36]

Studies[37,38] have suggested a higher prevalence of migraine among adolescent and adult females, whereas others[39,40] reported minimal sex differences in prevalence during the preadolescent period. Our findings indicate that the incidence, prevalence and DALYs of migraine among female children and adolescents are higher than those among males, a disparity attributable to multiple interacting factors. From a biological perspective, evidence suggests that women may be more susceptible to genetic variants associated with migraine.[41] Fluctuations in oestrogen levels during adolescence may trigger migraine by affecting hypothalamic function and neuronal excitability, while testosterone may confer a protective effect in males.[40] From psychosocial aspects, females may exhibit greater vulnerability to stressors and sleep disturbances, which can interact with biological mechanisms to promote migraine onset. Additionally, women generally demonstrate higher pain sensitivity, while men's heightened tolerance and negative attitudes towards pain may amplify this disparity.[42] It is noteworthy that our study revealed a more rapid burden growth occurring in men, suggesting that the male migraine burden should not be overlooked. One possible explanation is that the historically greater focus on female migraine may have led to underdiagnosis and undertreatment among males.[43] In recent years, awareness and reporting willingness among men may have increased with the spread of health education, contributing to the rise in reported rates. Behavioral factors may also play a role; for instance, increased screen time and consumption habits of caffeinated beverages among adolescent males are known risk factors for migraine.[44,45] Therefore, future public health strategies should continue to prioritise the high burden among women while strengthening the focus on male populations, particularly in prevention and early intervention.

Previous research has found that migraine often manifests before the age 18, rather than in adulthood as previously thought.[46] Our age-stratified analyses further reveal that the highest incidence of migraine in 2021 occurred among individuals aged 10–14 years, underscoring the high risk of young adolescents. Besides, both the prevalence and DALYs of migraine increased with age, peaking at 15–19 years, with the fastest increase in all ASRs. The ages of 10–14 years for females and 15–19 years for males represent critical stages of adolescent development, characterized by significant neurological, hormonal, psychological, behavioral, and academic changes. During this period, adolescents encounter various challenges, including escalating use of electronic devices, sedentary lifestyles, and psychological stress, all of which may contribute to the growing migraine burden.[44] Consequently, there is a particular urgency to implement management strategies tailored to this age group, emphasizing lifestyle interventions, headache education, non-pharmacological treatments, and early identification.[47]

Our findings underscore the urgency of prioritizing awareness raising, ongoing monitoring, and effective interventions for migraine in children and adolescents in future research. The limited progress in reducing the global burden of migraine may largely stem from insufficient education.[48]

It is essential to enhance educational initiatives targeting the general public, healthcare professionals, and policy-makers, and to integrate children and adolescent migraine into global and national NCD surveillance agendas. Also, consensus-standardised methods should be employed to fill gaps in epidemiological data for children under five years of age and low-income countries. The structured program of headache services promoted by the GCH, which is based on primary health care, has been demonstrated to be a viable solution.[30] Future research should focus on developing more accessible and effective pharmacological and non-pharmacological treatment strategies, as well as defining optimal clinical practices and care strategies within structured program. Moreover, healthy lifestyle interventions are important for the prevention and long-term management. For instance, the the American "Whole School, Whole Community, Whole Child" model facilitates the coordination of dietary, physical activity, mental health, and other health policies.[49] Finally, global cooperation should be strengthened to enhance assistance for LMICs, facilitate resource sharing and technological exchange among nations, and actively advance telemedicine and digital health tools to bridge service gaps in resource-deprived regions.

This study has several limitations. First, these results are derived from the GBD 2021 database, which has inherent limitations. For example, variations in data quality and missing raw data, especially in conflict-affected and resource-poor low-income countries, may lead to possible underestimates and inaccuracies in the findings. To mitigate these concerns, we adopted a multi-level analysis to ensure the robustness and reliability of the results. Second, the International Classification of Headache Disorders criteria have been revised multiple times over the past 32 years, together with iterations of GBD modelling techniques, which may introduce uncertainty in the estimates. Nevertheless, this uncertainty is expected to decrease as both diagnostic criteria and modeling methods continue to evolve. Lastly, the GBD database currently does not classify migraine subtypes and lacks data for children under 5 years old and for some low-income countries. It is anticipated that GBD 2023 will provide more comprehensive data on migraine in children and adolescents with the expanded implementation of GCH in low-income regions.

Conclusion

Over the past 32 years, the burden of migraine in children and adolescents has trended upward, more significantly among adolescents aged 15–19 years, males, regions with middle and higher SDI, East Asia, and Norway. Currently, the burden is heaviest among adolescents aged 15–19, females, and low–middle SDI regions. However, the greatest potential for improvement lies in middle and higher SDI regions, especially Brazil. These results highlight that migraine in children and adolescents has become an escalating global public health problem with inequities in public health services. Addressing this will require coordinated efforts from society, including individuals, schools, health-care providers, and policymakers, through strengthening public education and developing new treatments to raise awareness and promote effective management. Besides, for resource-poor countries, ongoing international collaboration and the development of customised management strategies tailored to their needs and actual resources are essential.

Abbreviations

AAPCs, Average annual percentage changes; ASRs, Age-standardised rates; ASIR, Age-standardised incidence rate; ASPR, Age-standardised prevalence rate; ASDR, Age-standardised DALYs rate; CI, Confidence interval; DALYs, Disability-adjusted life-years; GBD, Global Burden of Disease; GCH, Global Campaign against Headache; LMICs, low- and middle-income countries; NCD, Non-communicable disease; SDI, Socio-demographic index; UI, Uncertainty interval; WHO, World Health Organization.

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Disclosure

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