The Journal of Headache and Pain

RESEARCH

Open Access

Characterizing migraine burden and treatment response using nationwide smartphone app-based data in Korea

Hong-Kyun Park[1], Yunha Noh[2,3], Min Kyung Chu[4], Ju-Young Shin[3,5], Yu-Jin Shin[6], Ha-Yeong Gil[6], Min-Taek Lee[6] and Byung-Kun Kim[7*]

Abstract

Background Migraine is a major source of disability in Korea, yet many patients remain underdiagnosed or undertreated. Traditional epidemiological studies are limited by recall bias and incomplete patient-reported outcomes. App-based headache diaries offer real-time, repeated measures of symptoms and treatment, enabling large-scale assessment to better understand migraine burden and treatment response. This study aimed to evaluate the large-scale implementation of a nationally distributed smartphone "Headache Diary" mobile application and describe migraine burden, acute treatment response, and functional impairment in real-world practice in Korea.

Methods We conducted a retrospective, non-interventional analysis using self-reported data from the nationwide "Headache Diary" mobile application, developed by the Korean Headache Society. We included users who submitted at least one headache report between December 2020 and January 2025. Migraine/probable migraine were identified using an algorithm based on medication use and ICHD-3 criteria, while the remaining participants were classified into a non-migraine group (including tension-type headache or unclassifiable headache disorders). Acute-treatment failure was defined as pain relief reported after 2 hours or no effect. We also analyzed clinical characteristics, acute treatment patterns, and functional impairment associated with headache attacks.

Results Of 23,713 users, 17,913 (75.5%) had migraine or probable migraine. Migraine patients experienced more severe headache intensity (55.5% vs. 13.7%), higher rates of premonitory symptoms (67.7% vs. 29.5%), more frequent identification of triggers (89.9% vs. 61.2%), and greater use of acute medications (73.1% vs. 23.8%) compared to non-migraine users. Among 211,302 headache attacks analyzed, 155,894 attacks were migraine, and 96,742 attacks were available for acute treatment effect assessment. Of the 86,301 triptan-treated attacks, 40.3% resulted in acute treatment failure. Adolescents (10–19 years) showed the highest failure rate (62.1%). Notably, attacks with premonitory symptoms (odds ratio [OR] 0.91, 95% CI 0.89–0.94), aura (OR 0.79, 95% CI 0.75–0.83), or potential triggers (OR 0.93, 95% CI 0.91–0.96) had lower odds of treatment failure. Functional impairment was reported in 36.6% of attacks, most as decreased work or study efficiency (21.0%) and reduced household activity efficiency (17.2%).

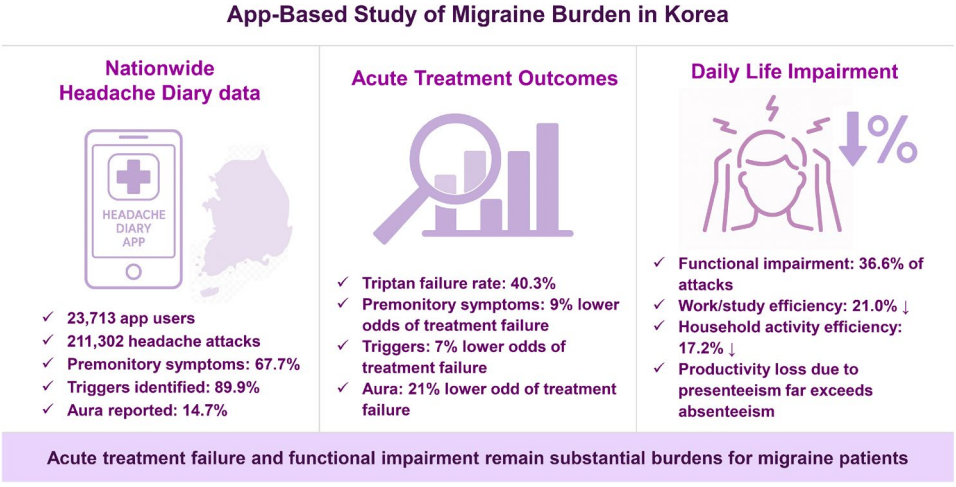
*Correspondence:
Byung-Kun Kim
kbk1403@eulji.ac.kr

Full list of author information is available at the end of the article

Conclusions Nationwide, app-based data revealed that migraine patients in Korea frequently experience severe attacks, premonitory symptoms, and triggers, with substantial rates of acute treatment failure and functional impairment. These findings highlight the need for earlier recognition and timely intervention and suggest that real-time digital platforms can provide valuable insights for patient-centered migraine management.

Clinical trial number Not applicable.

Graphical Abstract



Keywords Migraine, Headache diary, Mobile app, Real-world data, Acute treatment response, Patient-reported outcomes

Background

Migraine is one of the most prevalent and debilitating neurological disorders worldwide, affecting over one billion people. Recent Global Burden of Disease (GBD) estimates highlight the scale of headache-related disability: in 2023, headache disorders affected 2.9 billion people globally (age-standardized prevalence 34.6%) and generated an age-standardized YLD (Year(s) Lived with Disability) rate of 541.9 per 100,000 population. Migraine accounts for most headache-attributed disability, with an age-standardized YLD rate of 487.5 per 100,000 population in 2023 [1]. Despite advances in diagnostic criteria and therapeutic strategies, under-recognition, delayed diagnosis, and suboptimal treatment remain widespread, contributing to a considerable personal and societal burden [2–6]. Although traditional studies using retrospective surveys or claims data have clarified the epidemiology of migraine, results are often limited by recall bias, incomplete detail, and poor capture of patient-reported outcomes [7, 8]. In contrast, mobile health technologies offer a unique opportunity to obtain large-scale, real-time data, patterns and outcomes of treatment, and daily functional impact directly from patients. In particular, headache diary applications offer accessible means to collect real time data, enabling researchers and physicians to better understand patient experiences and treatment outcomes [9]. Studies using app-based data, such as the Migraine Buddy platform, have demonstrated the feasibility of capturing real-world burden of headache, treatment experiences across the world, and patient-centered treatment options [10, 11].

In Korea, migraine remains underdiagnosed and undertreated. Previous national data showed an average diagnostic delay of 10 years, and only one-quarter of individuals had consulted a physician for their headaches [12, 13]. Moreover, even among individuals who seek medical care for migraine, long-term adherence to treatment remains low [14], suggesting gaps in both patient awareness and continuity of care. To address these gaps, the Korean Headache Society developed a nationwide smartphone-based "Headache Diary" application to assist patients in systematically tracking headache attacks, associated features, medication use, and functional impact. However, no comprehensive data have been reported using the real-world data derived from this digital platform.

By using this digital platform-based dataset, this study aimed to evaluated the feasibility of large-scale real-world data collection and characterize the comprehensive migraine burden in Korea. Specifically, we investigated

the proportion of migraine and clinical characteristics of migraine presentations and analyzed patterns of acute treatment use, treatment responses, and self-reported disability.

Methods

Study design and data source

We conducted a retrospective, non-interventional study using self-reported data from the 'Headache Diary' mobile application, which was developed and launched in 2020 by the Korean Headache Society. The Headache Diary has been widely disseminated across clinical settings in Korea and is freely accessible to individuals experiencing headaches. To ensure broad accessibility for personal headache management, the application was distributed via the Google Play Store (Android) and Apple App Store (iOS). Participants were recruited through a variety of channels, including public media outreach (newspapers and online news), digital platforms such as YouTube, and official announcements on the Korean Headache Society website. Additionally, headache specialists directly introduced the application to patients during routine outpatient consultations. Participation was entirely voluntary; individuals chose to download the app and self-record their data without any direct incentives, targeting the Korean-speaking population. As the platform was primarily designed as a clinical tool for patient self-monitoring rather than a dedicated research instrument, no formal screening or inclusion procedures were applied at the point of download. App users can record structured headache data—location, quality, intensity, attack duration, potential triggers, premonitory symptoms, associated symptoms and postdromes, acute medication use and response, and daily impairment. Users can then monitor episodes longitudinally to track attack frequency, identify patterns, and evaluate treatment effect. The app automatically captures the weather conditions at the time of each recorded attack. To ensure participant privacy, all data recorded in the application were stored in a secure cloud-based system with anonymized patient identifiers. No personally identifiable information was collected or accessed during the study. In compliance with the Personal Information Protection Act of Korea, the research team only utilized de-identified datasets for analysis. This study was approved by the Institutional Review Board of Sungkyunkwan University (No. 2024–09-083). Due to the retrospective nature of the study, the need to obtain informed consent was waived.

Study population

The base cohort comprised all individuals with headaches who submitted at least one report in the Headache Diary app between December 1, 2020, and January 17, 2025. From the base cohort, we then identified patients with migraine using an algorithm based on medication history and diagnostic criteria adapted from the International Classification of Headache Disorders, 3rd edition (ICHD-3) (Fig. 1) [15]. First, all individuals who reported at least one intake of a triptan or ergotamine within the application were classified as migraine cases. Since triptans and ergotamine are strictly regulated as prescription-only medications in Korea requiring a formal physician's diagnosis, individuals reporting their intake of these

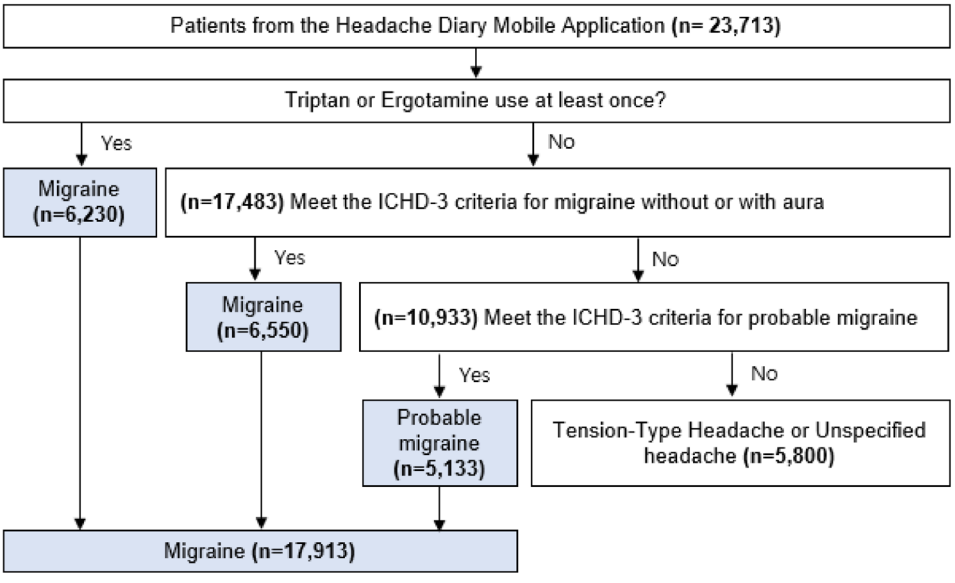


Fig. 1 Algorithm to identify patients with migraine

medications were regarded as migraine cases. Among individuals without use of triptan or ergotamine, we classified those with migraine with or without aura according to ICHD-3 criteria (Supplemental Table 1). For those who did not meet the criteria for migraine, the algorithm further assessed for probable migraine (ICHD-3 section 1.3) to identify individuals who fulfilled all but one of the required ICHD-3 criteria from B through D (i.e., missing either the required duration, at least two headache characteristics, or at least on associated symptom) (Supplemental Table 1). This stepwise, algorithmic approach ensured a standardized and clinically meaningful classification of headache types within the study population. The enrollment year was defined as the year that includes the individual's first headache-report date.

Units of analysis

We made two units for data analysis depending on the study objectives. For the first objective, which was to identify the proportion of migraine among all headaches, the unit of analysis was the individual in the base cohort (i.e., individuals with any headache). The index date was defined as the start date of the headache in the patient's first recorded report. For the second objective—to estimate acute treatment responses and the number of days with functional impairment due to migraine—the unit of analysis was headache attack among individuals with migraine. In this context, the index date was defined as the start date of the headache for each attack. Headache attacks were defined using an algorithm that incorporated explicit headache duration, medication use, and inferred durations from subsequent diary reports. To ensure the reliability of the analyzed data and minimize the potential inclusion of accidental or non-meaningful entries, single-entry records were excluded only in cases where the attack duration could not be determined (e.g., no recorded duration, no medication use, and no subsequent report within 24 hours) (Fig. 2).

Data collection

We collected the information on demographics (birth year, age, and sex), the date of the first headache report on the app, headache start and termination date and time (hours and minutes) for each episode, and weather conditions (barometric pressure, humidity, and temperature) of each attack. Clinical characteristics of headaches were also obtained, including headache intensity (rated on a 1–10 scale, mild for 1–3, moderate for 4–6, and severe for 7–10), location of pain (categorized into 14 anatomical regions according to anterior, lateral, posterior, and cervical distribution), headache quality (throbbing, tightening, exploding, or sharp), premonitory symptoms (feeling of impending pain, stiffness or tightness in the back of the neck, yawning, fatigue, mood changes, appetite changes, photophobia, phonophobia, or osmophobia), and aura (symptoms lasting between 5 and 60 minutes, gradual onset over more than 5 minutes, visual disturbances, zigzag lines [fortification patterns], unilateral symptoms, language difficulties or slurred speech, and numbness or tingling in parts of the body). Additional information was also collected regarding the headache associated symptoms (indigestion, nausea, vomiting, dizziness,

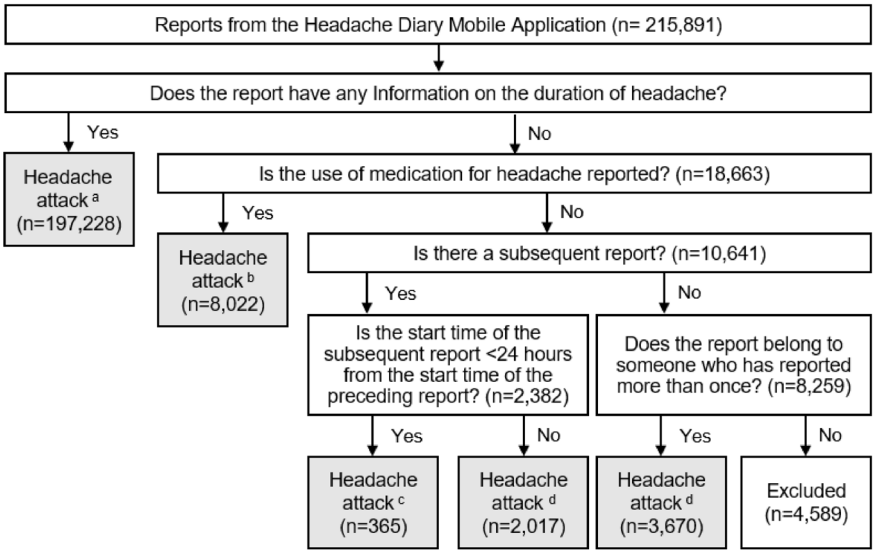


Fig. 2 Algorithm to define headache attacks and their durations

worsening with movement, photophobia, phonophobia, osmophobia, stiffness or tightness in the back of the neck, tearing or redness of the eyes, and runny nose or nasal congestion), and headache triggers (stress, fatigue, lack of sleep, napping or late sleeping, weekends, fasting, overeating, indigestion, light, sound, smell, cold, exercise, alcohol, and menstruation). The daily impairment due to headache was also recorded and categorized as absence from work or school, decreased work or study efficiency, inability to perform household activities, decreased efficiency in household activities, or inability to participate in leisure activities.

Statistical analysis

We compared the characteristics of participants with migraine and those with non-migraine headaches in the base cohort. We also described the distribution of characteristics across individual headache attacks. Continuous variables are presented as mean ± standard deviation (SD) or median with interquartile range (IQR), while categorical variables are reported as frequency with percentage.

Headache attack durations were primarily analyzed based on user-reported data. In cases where users recorded the onset of a headache but failed to provide an end time, the duration was imputed using a predefined logic. For subsequent attacks reported within 24 hours, the duration was calculated as the time interval between the onset of the index attack and the start of the following entry. If the next attack was reported after 24 hours, we performed a simple imputation using the most frequent reported duration (mode) in the dataset (Fig. 2).

Acute treatment success was defined as the pain freedom or relief reported within 2 hours, whereas acute treatment failure was defined as not being pain freedom or relief within 2 hours, including reports of "no effect". We estimated the risk of acute treatment failure based on the onset time of treatment efficacy among participants with migraine. We also estimated the risk of acute treatment failure stratified by age, sex, and several clinical characteristics including headache intensity, triggers, aura, premonitory symptoms, and type of treatment. Crude and adjusted odds ratios (OR) with 95% confidence intervals (CI) were calculated using univariate and multivariate logistic regression, respectively. To account for potential within-person correlation across repeated attacks, we conducted a sensitivity analysis using generalized estimating equations (GEE) with a logit link and binomial distribution. Lastly, we quantified the number of headache attacks with functional impairment among all migraine attacks, stratified by type of daily activity affected. In addition, to enhance the objectivity of functional impairment, we compared headache intensity and duration between attacks with and without reduced work efficiency—defined as the presence of either decreased work/study efficiency or decreased efficiency in household activities—using two-sample t tests.

Results

Characteristics of headache attacks

Of the 215,891 reports submitted via the Headache Diary app, a total of 211,302 reports were classified as headache attacks following the algorithm in the Fig. 2. The characteristics of headache attacks are described in the Table 1. Of the 211,302 analyzed attacks, the headache duration was directly reported by users in 93.3% (n = 197,228) of cases, and median duration was 7.6 [3.0–14.9] days. The median headache intensity was 5.0 (3.0–6.0), with 24.8% classified as severe. Nearly half of attacks (48.7%) were preceded by premonitory symptoms, most commonly feeling of impending pain (35.8%) followed by stiffness/tightness in the back of the neck. Individuals became aware of premonitory symptoms a median of 1 (0.5–2) hour before headache starts. Associated symptoms were present in 76.6% of attacks with stiffness/tightness in the back of the neck in nearly half of the cases. Acute medications were used in 62.9% of all attacks, among which triptans accounted for 61.1% (Table 1).

Comparison of headache characteristics between individuals with migraine and individuals without migraine

Of 23,713 users of the Headache Diary app, 17,913 were classified as having migraine or probable migraine and the remaining 5,800 users were classified as having tension-type or unspecified headache (Fig. 1, Table 2). Compared to individuals without migraine, individuals with migraine were more likely to experience severe headache intensity (55.5% vs. 13.7%), report premonitory symptoms (67.7% vs. 29.5%), identify potential triggers (89.9% vs. 61.2%), and use acute medications (73.1% vs. 23.8%). Individuals with migraine had more days with functional impairment due to headache than those without migraine, both per patient (median 3.0 vs. 1.0 days) and per month (median 1.1 vs. 0.9 days) (Table 2).

Acute treatment effectiveness, predictors of failure, and daily functional impact

Of 155,894 migraine attacks, information on acute treatment effect was available for 96,742 attacks (Table 3). Among 86,301 (89.2%) attacks treated with triptans, 38.2% achieved acute treatment success within 1 hour and 21.6% within 2 hours, while 40.3% were classified as treatment failures (Table 3). The proportion of acute treatment failure varied by demographic and clinical subgroups (Table 4). Individuals with 10–19 years showed the highest failure rate (62.1%; OR 1.73, 95% CI 1.55–1.94). Treatment failure was more frequent in

Table 1 Characteristics of headache attacks

Characteristics	Headache Attacks (N = 211,302)
Demographic characteristics	
Female sex, n (%)	180,750 (85.5)
Environmental characteristics	
Barometric pressure, mean ± SD, hPa	1015.8 ± 21.6
Humidity, mean ± SD, %	64.7 ± 21.0
Temperature, mean ± SD, °C	15.0 ± 10.8
Clinical characteristics	
Duration of attacks, hours	
Mean ± SD	11.6 ± 18.8
Median (IQR)	7.6 (3.0–14.9)
Headache intensity, scores	
Mean ± SD	4.7 ± 2.3
Median (IQR)	5.0 (3.0–6.0)
1–3 (mild)	69,465 (32.9)
4–6 (moderate)	89,439 (42.3)
7–10 (severe)	52,398 (24.8)
Unilateral pain, n (%)	68,469 (32.4)
Quality of headache, n (%)	
Throbbing	104,560 (49.5)
Tightening	42,450 (20.1)
Exploding	9,290 (4.4)
Sharp	14,202 (6.7)
Premonitory symptoms, n (%)	102,801 (48.7)
Awareness of premonitory symptoms before headache start, median (IQR), hours	1.0 (0.5–2.0)
Feeling of Impending Pain	75,542 (35.8)
Stiffness/Tightness in the Back of the Neck	59,390 (28.1)
Yawning	20,678 (9.8)
Fatigue	44,293 (21.0)
Mood Changes	7,038 (3.3)
Appetite Changes	16,526 (7.8)
Photo-, phono- or osmophobia	16,095 (7.6)
Associated symptoms, n (%)	161,949 (76.6)
Indigestion	55,320 (26.2)
Nausea	74,218 (35.1)
Vomiting	13,741 (6.5)
Dizziness	66,873 (31.6)
Worsened by Movement	49,880 (23.6)
Photophobia	49,650 (23.5)
Phonophobia	46,266 (21.9)
Osmophobia	33,710 (16.0)
Stiffness/Tightness in the Back of the Neck	101,835 (48.2)
Tearing/Redness of the Eyes	20,337 (9.6)
Runny Nose/Nasal Congestion	22,984 (10.9)
Acute medication use, n (%)	
Any medication	132,842 (62.9)
Triptans	81,134 (38.4)
Ergotamine	4,638 (2.2)
Unknown/Other medications	65,597 (31.0)

Triptans included in sumatriptan, zolmitriptan, naratriptan, almotriptan, and frovatriptan

Other medications refer to agents other than triptans or ergotamine

moderate-to-severe attacks compared with mild attacks. Notably, the likelihood of treatment failure was lower in attacks with premonitory symptoms (OR 0.91, 95% CI 0.89–0.94), aura (OR 0.79, 95% CI 0.75–0.83), or potential triggers (OR 0.93, 95% CI 0.91–0.96). After adjustment for clinically relevant covariates, the risk of acute treatment failure in the adolescent group (10–19 years) decreased significantly (adjusted OR 0.53, 95% CI 0.45–0.62). For the remaining variables, the directions and strengths remained largely consistent with the patterns observed in the crude analysis.

Among 211,302 headache attacks, 36.6% were associated with functional impairment in daily activities (Table 5). The most commonly affected activity was decreased work or study efficiency (21.0%), followed by decreased efficiency in household activities (17.2%). Less frequently reported impairments included inability to perform household activities (5.3%), inability to participate in leisure activities (4.9%), and absence from work or school (1.6%). Headache attacks with reduced work/study efficiency (presenteeism) showed higher mean intensity (5.3±2.1 vs. 4.5 ± 2.3, $p < 0.01$) and an extended mean duration (13.1±22.3 vs. 11.0 ± 16.6, $p < 0.01$) than those without such impairment (Supplemental Table 3).

Discussion

This nationwide, app-based study of over 23,000 users and 210,000 headache attacks demonstrated several key findings. Compared with individuals without migraine, individuals with migraine were more likely to experience severe intensity, premonitory symptoms, potential triggers, and acute medication use. Despite frequent triptan use, about 40% of treated attacks resulted in treatment failure, particularly among adolescents and in moderate-to-severe attacks, whereas attacks with premonitory symptoms, aura, or triggers showed lower failure rates. More than one-third of attacks were linked to functional impairment, most commonly reduced work, study, or household efficiency, highlighting the daily burden of migraine.

Clinical characteristics and symptom recognition

Among these findings, the high prevalence of severe headache intensity and premonitory symptoms in individuals with migraine is particularly noteworthy. More than half of the individuals with migraine reported attacks of severe intensity, which is consistent with the substantial clinical burden documented in previous studies [3, 16]. The high prevalence of premonitory symptoms (67.7%) and triggers (89.9%) in our study aligns with previous real-time diary and app-based studies, where patients frequently recognized early symptoms via electronic diaries [17], or showed similar pooled estimated relative frequency (66%, 95% CI 45–82) in clinic-based

Table 2 Baseline characteristics of patients with migraine and non-migraine headaches

Characteristics	All patients N = 23,713	Migraine, n (%) n = 17,913 (75.5)	Non-migraine, n (%) n = 5,800 (24.5)
Demographic characteristics*			
Enrollment, n (%), years			
2020 (December~)	244 (1.0)	201 (1.1)	43 (0.7)
2021	10,864 (45.8)	7,646 (42.7)	3,218 (55.5)
2022	5,396 (22.8)	4,311 (24.1)	1,085 (18.7)
2023	3,529 (14.9)	2,812 (15.7)	717 (12.4)
2024	3,576 (15.1)	2,870 (16.0)	706 (12.2)
2025 (~January)	104 (0.4)	73 (0.4)	31 (0.5)
Age group, n (%)			
10s	1,572 (6.6)	1,148 (6.4)	424 (7.3)
20s	6,755 (28.5)	4,818 (26.9)	1,937 (33.4)
30s	7,042 (29.7)	5,565 (31.1)	1,477 (25.5)
40s	4,859 (20.5)	3,856 (21.5)	1,003 (17.3)
50s	2,249 (9.5)	1,713 (9.6)	536 (9.2)
60s+	525 (2.2)	333 (1.9)	192 (3.3)
Unknown	711 (3.0)	480 (2.7)	231 (4.0)
Female sex, n (%)	20,334 (85.8)	15,440 (86.2)	4,894 (84.4)
Headache characteristics†			
Frequency of headache attacks per patient			
Mean ± SD	8.9 ± 29.8	11.5 ± 33.8	0.9 ± 4.7
Median (IQR)	2.0 (1.0–5.0)	3.0 (1.0–8.0)	0.0 (0.0–1.0)
Frequency of headache attacks, times per month‡			
Mean ± SD	3.5 ± 4.0	3.5 ± 4.0	4.0 ± 5.9
Median (IQR)	2.4 (1.1–4.5)	2.4 (1.1–4.5)	2.1 (1.3–4.7)
Severe intensity, n (%)[§]	10,733 (45.3)	9,941 (55.5)	792 (13.7)
Premonitory symptoms, n (%)	13,833 (58.3)	12,122 (67.7)	1,711 (29.5)
Aura, n (%)	3,490 (14.7)	3,490 (19.5)	-
Potential triggers, n (%)	19,655 (82.9)	16,103 (89.9)	3,552 (61.2)
Acute medication, n (%)	14,472 (61.0)	13,091 (73.1)	1,381 (23.8)
Triptans, n (%)	5,903 (24.9)	5,903 (33.0)	-
Ergotamine, n (%)	550 (2.3)	550 (3.1)	-
Unknown/Other medications, n (%)	11,827 (49.9)	10,446 (58.3)	1,381 (23.8)
Disability due to headache			
Duration with functional impairment per patient			
Mean ± SD	7.4 ± 26.6	8.4 ± 28.6	1.5 ± 1.0
Median (IQR)	2.0 (1.0–5.0)	3.0 (1.0–6.0)	1.0 (1.0–2.0)
Duration with functional impairment, days per month‡			
Mean ± SD	2.4 ± 4.1	2.4 ± 4.1	1.7 ± 2.2
Median (IQR)	1.1 (0.4–2.9)	1.1 (0.4–2.9)	0.9 (0.6–1.7)

The unit of analysis is the patient. The index date was defined as the enrollment date (i.e., the date of the first reported headache attack) in the mobile application

Measured in the index date

Measured during the entire enrollment period in each patient

Average of total times or days per patient per month. Restricted to patients with an enrollment period of 30 days or longer ($n = 6740$; migraine $n = 6659$, non-migraine $n = 81$)

7–10 scores

studies [18]. Likewise, app-based diary studies have documented that more than 70% of migraine patients reported triggers as precipitating migraine attacks in real-world settings [9, 19]. These findings underscore the heterogeneity of migraine attacks and highlight the value of patient-reported, real-time data in capturing features that are often underrepresented. Importantly, the ability to document premonitory symptoms and triggers in real time may inform strategies for earlier recognition and more timely initiation of acute therapy.

Table 3 Distribution of acute treatment responses in migraine attacks

Type of Medication	Migraine Attacks, N	Acute Treatment Success		Acute Treatment Failure	
		Pain freedom or relief within 1 hour	Pain freedom or relief within 2 hours	Pain freedom or relief within 4 hours	No Effect
Any medication use	96,742	33,189 (34.3)	18,796 (19.4)	43,711 (45.2)	1,046 (1.1)
Triptans	86,301	32,928 (38.2)	18,608 (21.6)	33,804 (39.2)	961 (1.1)

Table 4 Distribution of acute treatment responses according to Demographic and clinical characteristics

Characteristics	Headache Attacks, N	Acute Treatment Success		Acute Treatment Failure		Odds ratio (95% CI)	
		Pain freedom or relief within 1 hour	Pain freedom or relief within 2 hours	Pain freedom or relief within 4 hours	No Effect	Crude	Adjusted
Age group							
10s	1,317	305 (23.2)	194 (14.7)	797 (60.5)	21 (1.6)	1.73 (1.55–1.94)	0.53 (0.45–0.62)
20s	13,074	4,455 (34.1)	2,982 (22.8)	5,515 (42.2)	122 (0.9)	0.80 (0.77–0.84)	0.75 (0.71–0.78)
30s	29,341	9,233 (31.5)	6,367 (21.7)	13,300 (45.3)	441 (1.5)	0.93 (0.90–0.96)	1.00 (0.97–1.03)
40s	31,407	10,754 (34.2)	5,383 (17.1)	14,990 (47.7)	280 (0.9)	(reference)	**(reference)**
50s	17,647	7,443 (42.2)	2,832 (16.0)	7,220 (40.9)	152 (0.9)	0.76 (0.73–0.79)	0.87 (0.84–0.91)
60s+	2,532	653 (25.8)	650 (25.7)	1,214 (47.9)	15 (0.6)	1.00 (0.92–1.08)	1.02 (0.94–1.11)
Sex							
Male	13,410	4,118 (30.7)	2,938 (21.9)	6,270 (46.8)	84 (0.6)	(reference)	**(reference)**
Female	83,612	29,085 (34.8)	15,858 (19.0)	37,704 (45.1)	965 (1.2)	0.96 (0.92–1.00)	0.92 (0.89–0.96)
Headache intensity							
Mild	26,267	9,163 (34.9)	5,233 (19.9)	11,755 (44.8)	116 (0.4)	(reference)	**(reference)**
Moderate	42,342	14,173 (33.5)	8,258 (19.5)	19,514 (46.1)	397 (0.9)	1.08 (1.04–1.11)	1.07 (1.04–1.11)
Severe	28,133	9,853 (35.0)	5,305 (18.9)	12,442 (44.2)	533 (1.9)	1.04 (1.00–1.07)	0.98 (0.94–1.02)
Premonitory symptoms	54,461	18,689 (34.3)	11,115 (20.4)	24,052 (44.2)	605 (1.1)	0.91 (0.89–0.94)	0.97 (0.94–0.99)
Aura	7,002	2,917 (41.7)	1,226 (17.5)	2,758 (39.4)	101 (1.4)	0.79 (0.75–0.83)	0.78 (0.74–0.83)
Potential triggers	69,841	24,480 (35.1)	13,390 (19.2)	31,152 (44.6)	819 (1.2)	0.93 (0.91–0.96)	0.96 (0.93–0.99)
Type of treatment							
Triptans	86,301	32,928 (38.2)	18,608 (21.6)	33,804 (39.2)	961 (1.1)	(reference)	**(reference)**
Other than triptans	10,441	261 (2.5)	188 (1.8)	9907 (94.9)	85 (0.8)	32.99 (29.98–36.30)	47.87 (39.23–58.41)

Table 5 The number of days with functional impairment due to migraine by type of daily activities (total headache attacks, $n = 211302$)

Type of Daily Activities	Attacks with Functional Impairment, n (%)
Any limitations of daily activities	75,558 (36.6)
Absence from Work/School	3,385 (1.6)
Decreased Work/Study Efficiency	43,375 (21.0)
Unable to Perform Household Activities	10,990 (5.3)
Decreased Efficiency in Household Activities	35,500 (17.2)
Unable to Participate in Leisure Activities	10,011 (4.9)

Treatment response and potential determinants

In our study, even though triptans were used in nearly 90% of migraine attacks, approximately 40% of triptan-treated attacks resulted in treatment failure. While this figure appears lower than the 56% failure rate from the American Migraine Prevalence and Prevention (AMPP) study [20], direct comparison is limited due to differing efficacy endpoint (2-hour pain relief in our study vs. pain freedom in AMPP study). We identified age-related differences in treatment response: individuals in teens (10–19 years) showed the highest likelihood of failure, whereas middle-aged patients exhibited lower failure rates. Several factors might contribute to this disparity. Locally, the less frequent use of triptans in teens (15.2%; Supplemental Table 2) might be due to Korean regulatory restrictions, where most triptans (except almotriptan for those aged 15 or older) are not approved for patients under 18, severely limiting acute treatment options in this age group (10–19 years). Beyond these institutional constraints, our study demonstrated that migraine attacks were more likely to be treated successfully when accompanied by premonitory symptoms, aura, or potential triggers. The TEMPO study demonstrated that early triptan dosing yielded higher 2-hour pain freedom rates compared to late dosing (52.8% vs. 30.2%) [21], and recent

evidence suggests that gepants administered during the prodromal phase can effectively prevent moderate-to-severe headaches [22]. However, our findings revealed that adolescents (10–19 years) reported significantly lower frequencies of premonitory symptoms and potential triggers compared with other age groups (34% vs. 49–66%; Supplemental Table 4). This discrepancy might suggest a recognition delay in younger patients. Adolescents often fail to identify a migraine until pain intensity becomes severe [23] and report fewer, less consistent prodromes due to a still-maturing nervous system [24, 25]. This recognition delay inherently leads to treatment delay, causing patients to miss the optimal window for early dosing. Psychiatric comorbidities, such as anxiety and depression, might be associated with increased headache profiles; higher baseline levels of these conditions are associated with increased pain intensity, frequency, and duration in adolescent migraine patients [26]. In addition, lower adherence to treatment or recommendations including poor lifestyle modification [27] and discrepancies between self-reported medication intake and objective measures [28] can further compromise clinical outcomes in this population. Adolescents exhibit more robust central sensitization than adults with allodynia rate reaching up to 96.6% [29]. This heightened physiological sensitivity might be associated with diminished responsiveness to acute treatment. These findings raise the hypothesis that attacks with premonitory symptoms, aura, or triggers may be associated with earlier treatment initiation and better outcomes. However, as our dataset does not record the exact interval from headache onset to medication intake, this interpretation remains speculative. Alternative explanations also warrant consideration. Individuals identifying warning signs may possess superior self-management skills, utilizing non-pharmacological strategies such as lifestyle or stress management to complement drug efficacy [30]. Furthermore, headache subtypes with prominent premonitory features or aura might reflect a distinct biological profile; for instance, higher polygenic risk scores have been linked specifically to better triptan responsiveness [31]. Our observations may thus reflect an inherent biological predisposition toward better treatment response in certain subgroups rather than a direct causal relationship.

Functional impairment and productivity loss

Our results showed that 36.6% of migraine attacks were associated with functional impairment, most often manifesting as reduced efficiency, while complete absence from work or school was relatively uncommon. This underscores presenteeism as a key contributor to migraine-related disability. A study conducted in Japan showed that presenteeism accounted for a significantly higher economic loss ($375.4 USD/year/person) than absenteeism ($238.3 USD/year/person) [32]. In addition, a workplace-based study found that approximately 89% of migraine-related productivity loss was attributable to presenteeism [33]. Together, these findings highlight that the hidden burden of reduced productivity, although less visible than missed workdays, represents the dominant component of migraine-related disability and should be a major focus of future clinical management and health policy.

Strengths and limitations

Our study has several distinct advantages compared to previous digital health research. While most existing headache diary studies have focused on symptom prevalence [34, 35] or trigger identification [9, 17], we evaluated real-world acute treatment response at the attack level using a large-scale, nationwide dataset. By analyzing outcomes from 96,742 treated attacks, we provide robust insights into the effectiveness of real-world migraine management that are often missing from traditional epidemiological surveys. Furthermore, as the majority of large-scale app-based studies have been conducted in Western settings, this research provides essential region-specific evidence from South Korea. This contributes to a more global understanding of migraine burden and highlights how local clinical practices and regulatory environments may influence treatment outcomes.

This study has several limitations. First, potential selection bias and limited generalizability may have been introduced due to the study's reliance on a voluntary, smartphone-based platform. Because users were predominantly young to middle-aged adults who are more familiar with digital tools, the findings may not be generalizable to older populations who are less likely to utilize mobile applications. Furthermore, the study population may overrepresent individuals with a higher headache burden, higher motivation, or greater health awareness, potentially leading to an overestimation of headache intensity and treatment failure rates. Second, the classification algorithm for migraine and probable migraine used in this study has not been formally validated against a clinical gold standard, such as a neurologist's diagnosis based on a structured clinical interview. This may introduce misclassification bias, including both false-positive and false-negative identification of cases. While we utilized key diagnostic elements from the ICHD-3 criteria to reflect real-world reporting patterns, the algorithm may not fully capture the clinical complexity typically assessed during in-person evaluations. In particular, the application did not systematically screen for 'red flags' that are essential for identifying secondary headache disorders. Consequently, some cases of secondary headaches or tension-type headaches may have been inadvertently misclassified as migraine. Future research incorporating

clinician-confirmed validation or validation sub-studies is warranted to further assess the diagnostic performance of this digital tool. Third, although the application records information prospectively and in real time, recall bias and underreporting cannot be entirely excluded, particularly if patients failed to log every attack. Fourth, the absence of data on preventive medication use, psychiatric comorbidities, and socioeconomic status represents a significant limitation. The high treatment failure rates observed in this study may be attributed to inadequate preventive management or undertreated psychological factors. Fifth, the temporal sequence between reported factors (e.g., triggers, premonitory symptoms) and headache onset could not be fully determined, precluding causal inference. Sixth, although this study showed the association of premonitory symptoms, aura, or potential triggers with better treatment outcome, we cannot establish a causal relationship because the application used in this study does not record information on the timing of medication intake relative to headache onset. Seventh, because the app was freely accessible without clinical oversight, some users may have provided incomplete, inconsistent, or non-clinically meaningful data. To mitigate this, we applied predefined data-quality filters during attack construction (including exclusion of single-entry records with insufficient duration information) and used an ICHD-3–based stepwise algorithm for headache classification. Nevertheless, the possibility of non-serious or inaccurate entries—particularly among users without a formal diagnosis or clinical guidance—remains a limitation. Similarly, non-expert users might misinterpret or misreport complex neurological symptoms, such as aura, without professional guidance. The evaluation of acute treatment effectiveness is inherently subjective and may be influenced by individual patient expectations rather than standardized clinical assessments. Eighth, the definition of acute treatment success in this study was based on pain freedom or relief within 2 hours rather than the IHS-standard endpoint of pain freedom [36]. This choice was made to improve the usability of the application for the general population in a real-world setting, as reporting the time to perceived treatment effect is often more straightforward for general users. However, using pain relief may lead to an overestimation of treatment efficacy compared to studies using stricter criteria. Consequently, caution is required when comparing our findings directly with results from controlled clinical trials that utilize pain freedom as a primary endpoint. Finally, although large-scale digital data collection requires rigorous oversight, we prioritized privacy through the use of anonymized identifiers in strict compliance with Korea's Personal Information Protection Act. We believe this framework effectively balances the utility of real-world data with the ethical necessity of participant protection.

Conclusion

Utilizing a nationwide, app-based headache diary, we demonstrate that nearly 40% of triptan-treated attacks resulted in failure, with the rate reaching a peak of 62.1% in adolescents. More than one-third of attacks caused functional impairment, mainly reduced efficiency (presenteeism). These findings highlight the need for optimized treatment strategies across all age groups, with a particular focus on the adolescent population. We anticipate that this platform-based headache diary will facilitate early intervention via premonitory symptom recognition and serve as a framework for national monitoring and policy-making regarding productivity loss. Future app-based studies should incorporate preventive therapy, comorbidities, long-term outcomes, and more detailed self-reported data to better guide patient-centered migraine management.

Abbreviations

AMPP	American Migraine Prevalence and Prevention study
CI	Confidence Interval
DALY	Disability-Adjusted Life Year(s)
GBD	Global Burden of Disease (Study)
ICHD-3	International Classification of Headache Disorders, 3rd edition
IQR	Interquartile Range
IRB	Institutional Review Board
OR	Odds Ratio
SD	Standard Deviation
TEMPO	Early dosing and efficacy of triptans in acute migraine treatment study
YLD	Year(s) Lived with Disability

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s10194-026-02370-7.

Supplementary Material 1

Acknowledgements

Not applicable.

Author contributions

BK, MKC, HKP, JYS were responsible for study design and data interpretation. JYS and YN performed data analysis. BK, HKP, MKC, JYS, YN, HYG, YJS, and MTL made contributions to manuscript writing and review. All authors read and approved the final manuscript.

Funding

This study is sponsored by Pfizer Pharmaceuticals Korea Limited.

Data availability

The datasets generated and/or analysed during the current study were obtained from the Headache Diary application operated by the Korean Headache Society. The results of this study are proprietary to Pfizer Pharmaceuticals Korea Limited and cannot be shared publicly due to company policy and data ownership restrictions.

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Boards of the following institutions:

Eulji Medical Center Seoul (EMCS IRB approval number: 2024–09-017), Inje University Ilsan Paik Hospital (ISPAIK IRB approval number: 2024–09-018), Severance Hospital, Yonsei University College of Medicine (IRB approval number: 4–2024–1085), Sungkyunkwan University (SKKU IRB approval number: 2024–09-083) Due to the retrospective nature of the study, the requirement for informed consent was waived by all participating IRBs. This study was conducted in accordance with the Declaration of Helsinki.

Consent for publication
Not applicable

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Neurology, Inje University Ilsan Paik Hospital, Inje University College of Medicine, Goyang, Gyeonggi-do, Republic of Korea
[2]College of Pharmacy, Chonnam National University, Gwangju, Republic of Korea
[3]Department of Biohealth Regulatory Science, School of Pharmacy, Sungkyunkwan University, Suwon, Republic of Korea
[4]Department of Neurology, Severance Hospital, Yonsei University College of Medicine, Seoul, Republic of Korea
[5]Samsung Advanced Institute for Health Sciences & Technology, Sungkyunkwan University, Seoul, Republic of Korea
[6]Pfizer Biopharmaceuticals Group, Pfizer Pharmaceuticals Korea Limited, Seoul, Republic of Korea
[7]Department of Neurology, Nowon Eulji Medical Center, Eulji University School of Medicine, 68 Hangeulbiseok-Ro, Nowon-Gu, Seoul 01830, South Korea

Received: 10 November 2025 / Accepted: 11 April 2026
Published online: 24 April 2026

References

1. Hus AK, Xu YY, Steinmetz JD, Aalipour MA, Aalruz H, Abdulah DM, Aboagye RG, Abtahi D, Rumeileh SA, Aburuz S, Adnani QESAdonteng-Kissi OAffinito GAhmad DAhmadi NSAhmed AAhmed AAhmed SAI Zoubi MAMAlabbad SAI-Ajlouni YAlbashtawy MAlhalaiqa FNAlhumaidi AAli MUAli SSAl-Iede MAlmazan JUAlshahrani NZAltaf AAl-Wardat MAl-Worafi YMAlzoubi KHAmiri SAmusa GAAnderson DBAnil AArabloo JAravkin AYAreda D (2025 Dec 1) Global, regional, and national burden of headache disorders, 1990–2023: a systematic analysis for the Global burden of Disease study 2023. The Lancet Neurol 24(12):1005–1015. https://doi.org/10.1016/S1474-4422(25)00402-8
2. Ashina M, Katsarava Z, Do TP, Buse DC, Pozo-Rosich P, Özge A, Krymchantowski AV, Lebedeva ER, Ravishankar K, Yu S, Sacco S, Ashina S, Younis S, Steiner TJ, Lipton RB (2021) Migraine: epidemiology and systems of care. Lancet 397(10283):1485–1495. https://doi.org/10.1016/S0140-6736(20)32160-7
3. Cohen F, Brooks CV, Sun D, Buse DC, Reed ML, Fanning KM, Lipton RB (2024) Prevalence and burden of migraine in the United States: a systematic review. Headache: J Head Face Pain 64(5):516–532. https://doi.org/10.1111/head.14709
4. Buse DC, Powers SW, Gelfand AA, VanderPluym JH, Fanning KM, Reed ML, Adams AM, Lipton RB (2018) Adolescent perspectives on the burden of a Parent's migraine: results from the CaMEO study. Headache: J Head Face Pain 58(4):512–524. https://doi.org/10.1111/head.13254
5. Buse DC, Scher AI, Dodick DW, Reed ML, Fanning KM, Adams AM, Lipton RB (2016) Impact of migraine on the family: perspectives of people with migraine and their spouse/domestic partner in the CaMEO study. Mayo Clinic Proc 91(5):596–611. https://doi.org/10.1016/j.mayocp.2016.02.013
6. Buse DC, Fanning KM, Reed ML, Murray S, Dumas PK, Adams AM, Lipton RB (2019) Life with migraine: effects on relationships, career, and finances from the chronic migraine epidemiology and outcomes (CaMEO) study. Headache: J Head Face Pain 59(8):1286–1299. https://doi.org/10.1111/head.13613
7. Lipton RB, Stewart WF, Diamond S, Diamond ML, Reed M (2001) Prevalence and burden of migraine in the United States: data from the American migraine study II. Headache: J Head Face Pain 41(7):646–657. https://doi.org/10.1046/j.1526-4610.2001.041007646.x
8. Stewart WF, Yan X, Pressman A, Jacobson A, Vaidya S, Chia V, Buse DC, Lipton RB (2021) Combining patient reported outcomes and EHR data to understand population level treatment needs: correcting for selection bias in the migraine signature study. J Patient Rep Outcomes 5(1):132. https://doi.org/10.1186/s41687-021-00401-2
9. Park JW, Chu MK, Kim JM, Park SG, Cho SJ (2016) Analysis of trigger factors in episodic migraineurs using a smartphone headache diary applications. PLoS One 11(2):e0149577. https://doi.org/10.1371/journal.pone.0149577
10. Goadsby PJ, Constantin L, Ebel-Bitoun C, Igracki Turudic I, Hitier S, Amand-Bourdon C, Stewart A (2021) Multinational descriptive analysis of the real-world burden of headache using the migraine Buddy application. Euro J Neurol 28(12):4184–4193. https://doi.org/10.1111/ene.15037
11. Vo P, Paris N, Bilitou A, Valena T, Fang J, Naujoks C, Cameron A, de Reydet de Vulpillieres F, Cadiou F (2018) Burden of migraine in europe using self-reported digital diary data from the migraine Buddy© application. Neurol Ther 7(2):321–332. https://doi.org/10.1007/s40120-018-0113-0
12. Takeshima T, Wan Q, Zhang Y, Komori M, Stretton S, Rajan N, Treuer T, Ueda K (2019) Prevalence, burden, and clinical management of migraine in China, Japan, and South Korea: a comprehensive review of the literature. J Headache Pain 20(1):111. https://doi.org/10.1186/s10194-019-1062-4
13. Kim BK, Chu MK, Yu SJ, Dell'agnello G, Han JH, Cho SJ (2021) Burden of migraine and unmet needs from the patients' perspective: a survey across 11 specialized headache clinics in Korea. J Headache Pain 22(1):45. https://doi.org/10.1186/s10194-021-01250-6
14. Kim KY, Ko HY, Bea S, Lee HJ, Shin JY, Chu MK (2024) Treatment patterns and persistence among patients newly diagnosed with migraine in South Korea: a retrospective analysis of health claims data. J Clin Neurol 20(5):529–536. https://doi.org/10.3988/jcn.2023.0485
15. Korean Headache Society (2009) Migraine treatment guideline, 2nd edn edn. Korean Headache Society, Seoul
16. Amiri P, Kazeminasab S, Nejadghaderi SA, Mohammadinasab R, Pourfathi H, Araj-Khodaei M, Sullman MJM, Kolahi A-A, Safiri S (2022) Migraine: a review on its history, Global epidemiology, risk factors, and comorbidities. Front Neurol 12:800605. https://doi.org/10.3389/fneur.2021.800605
17. Giffin NJ, Ruggiero L, Lipton RB, Silberstein SD, Tvedskov JF, Olesen J, Altman J, Goadsby PJ, Macrae A (2003) Premonitory symptoms in migraine: an electronic diary study. Neurology 60(6):935–940. https://doi.org/10.1212/01.wnl.0000052998.58526.a9
18. Eigenbrodt AK, Christensen RH, Ashina H, Iljazi A, Christensen CE, Steiner TJ, Lipton RB, Ashina M (2022) Premonitory symptoms in migraine: a systematic review and meta-analysis of observational studies reporting prevalence or relative frequency. J Headache Pain 23(1):140. https://doi.org/10.1186/s10194-022-01510-z
19. Casanova A, Vives-Mestres M, Donoghue S, Mian A, Martin PR (2022) An observational study of self-reported migraine triggers and prospective evaluation of the relationships with occurrence of attacks enabled by a smartphone application (app). Headache: J Head Face Pain 62(10):1406–1415. https://doi.org/10.1111/head.14328
20. Lipton RB, Munjal S, Buse DC, Fanning KM, Bennett A, Reed ML (2016) Predicting inadequate response to acute migraine medication: results from the American migraine prevalence and Prevention (AMPP) study. Headache: J Head Face Pain 56(10):1635–1648. https://doi.org/10.1111/head.12941
21. Lantéri-Minet M, Mick G, Allaf B (2012) Early dosing and efficacy of triptans in acute migraine treatment: the TEMPO study. Cephalalgia 32(3):226–235. https://doi.org/10.1177/0333102411433042
22. Dodick DW, Goadsby PJ, Schwedt TJ, Lipton RB, Liu C, Lu K, Yu SY, Severt L, Finnegan M, Trugman JM (2023) Ubrogepant for the treatment of migraine attacks during the prodrome: a phase 3, multicentre, randomised, double-blind, placebo-controlled, crossover trial in the Usa. Lancet 402(10419):2307–2316. https://doi.org/10.1016/S0140-6736(23)01683-5
23. Kellier DJ, de Prado BM, Haagen D, Grabner P, Raj N, Lechtenberg L, Velasquez G, Hsu JY, Farrar JT, Hershey AD, Szperka CL (2023) Validity of self-reported migraine in adolescents and children. Headache 63(5):634–641. https://doi.org/10.1111/head.14498
24. C J-C (2019) Pediatric vs. Adult prodrome and postdrome: a window on migraine pathophysiology? Front Neurol 10:199. https://doi.org/10.3389/fneur.2019.00199
25. Gao L, Zhao F, Tu Y, Liu K (2024) The prodrome of migraine: mechanistic insights and emerging therapeutic strategies. Front Neurol 15:1496401. https://doi.org/10.3389/fneur.2024.1496401
26. Falla K, Kuziek J, Mahnaz SR, Noel M, Ronksley PE, Orr SL (2022) Anxiety and depressive symptoms and disorders in children and adolescents

with migraine: a systematic review and meta-analysis. JAMA Pediatrics 176(12):1176–1187. https://doi.org/10.1001/jamapediatrics.2022.3940
27. Kroon Van Diest AM, Ramsey R, Aylward B, Kroner JW, Sullivan SM, Nause K, Allen JR, Chamberlin LA, Slater S, Hommel K, LeCates SL, Kabbouche MA, O'Brien HL, Kacperski J, Hershey AD, Powers SW (2016) Adherence to biobehavioral recommendations in Pediatric migraine as Measured by electronic monitoring: the Adherence in migraine (AIM) study. Headache 56(7):1137–1146. https://doi.org/10.1111/head.12836
28. Reidy BL, Powers SW, Coffey CS, Chamberlin LA, Ecklund DJ, Klingner EA, Yankey JW, Korbee LL, Porter LL, Peugh J, Kabbouche MA, Kacperski J, Hershey AD, CHAMP Investigators (2022) Multimodal assessment of medication Adherence among youth with migraine: an ancillary study of the CHAMP trial. J Pediatr Psychol 47(4):376–387. https://doi.org/10.1093/jpepsy/jsab123
29. De Tommaso M, Sciruicchio V, Delussi M, Vecchio E, Goffredo M, Simeone M, Barbaro MGF (2017) Symptoms of central sensitization and comorbidity for juvenile fibromyalgia in childhood migraine: an observational study in a tertiary headache center. J Headache Pain 18(1):59. https://doi.org/10.1186/s10194-017-0764-8
30. Haghdoost F, Togha M (2022) Migraine management: non-pharmacological points for patients and health care professionals. Open Med (Wars) 17(1):1869–1882. https://doi.org/10.1515/med-2022-0598
31. Kogelman LJA, Esserlind A-L, Francke Christensen A, Awasthi S, Ripke S, Ingason A, Davidsson OB, Erikstrup C, Hjalgrim H, Ullum H, Olesen J, Folkmann Hansen T, International Headache Genetics Consortium (2019) Migraine polygenic risk score associates with efficacy of migraine-specific drugs. Neurol Genet 5(6), Article e364. https://doi.org/10.1212/NXG.0000000000000364
32. Shimizu T, Sakai F, Miyake H, Sone T, Sato M, Tanabe S, Azuma Y, Dodick DW (2021) Disability, quality of life, productivity impairment and employer costs of migraine in the workplace. J Headache Pain 22(1):29. https://doi.org/10.1186/s10194-021-01243-5
33. Begasse de Dhaem O, Sakai F (2022) Migraine in the workplace. eNeurologicalsci 27:100408. https://doi.org/10.1016/j.ensci.2022.100408
34. Larsson B, Fichtel Å (2012) Headache prevalence and characteristics among school children as assessed by prospective paper diary recordings. J Headache Pain 13(2):129–136. https://doi.org/10.1007/s10194-011-0410-9
35. Vandenbussche N, Van Der Donckt J, De Brouwer M, Steenwinckel B, Stojchevska M, Ongenae F, Van Hoecke S, Paemeleire K (2025) Tracking migraine symptoms: a longitudinal Comparison of smartphone-based headache diaries and clinical interviews. Neurol Int 17(3):33. https://doi.org/10.3390/neurolint17030033
36. Tfelt-Hansen P, Pascual J, Ramadan N, Dahlöf C, D'Amico D, Diener HC, Hansen JM, Lanteri-Minet M, Loder E, McCrory D, Plancade S, Schwedt T, International Headache Society Clinical Trials Subcommittee (2012) Guidelines for controlled trials of drugs in migraine: third edition. A guide for investigators. Cephalalgia: Int J Headache 32(1):6–38. https://doi.org/10.1177/0333102411417901

Publisher's Note