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Forecasting migraine attacks by managing daily lifestyle: a systematic review as a basis to develop predictive algorithms

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Abstract

Recent studies attempting to develop forecasting models for new migraine attack onsets, overviewing triggers and protectors, are encouraging but necessitate further improvements to produce forecasting models with high predictive accuracy. This updated review of available data holds the potential to enhance the precision of predicting a migraine attack. This study aims to evaluate how lifestyle factors affect migraine frequency in adults with episodic migraine, to contribute to the development of an effective migraine forecasting model. A comprehensive search of databases, including PubMed, ScienceDirect, Google Scholar, and Scopus, was conducted considering studies published from 2018 to December 2023, following the PRISMA guidelines. Critical evaluation was conducted using the Joanna Briggs Institute's appraisal tools. The lifestyle modifications examined in this review included dietary habits, physical activity, sleep, and stress management. Of the 36 studies analysed, which predominantly exhibited low to moderate bias, 18 investigated dietary habits, 7 explored physical activity, 11 assessed stress management, and 5 investigated sleep patterns. The evidence from these 36 studies advocates for the implementation of lifestyle modifications in migraine management. Furthermore, these outcomes carry valuable implications from the standpoint of migraine forecasting models. The most consistent results were observed in relation to specific diets, dietary supplements, and physical activity. Although trends were noted in stress management and sleep, further research is required to elucidate their influence on migraine frequency and their integration into a migraine forecasting model. This study is registered on PROSPERO (ID CRD42024511300).

Keywords: Episodic migraine, Forecasting, Prevention, Physiological triggers, Lifestyle, Diet, Physical activity, Stress, Sleep

1. Introduction

Migraine is a highly prevalent and disabling neurological disorder,[46] which leads to a high resource and cost burden. In the "Global Burden of Disease Study" of 2019,[67] it has been classified among the most prevalent conditions and among the leading causes of disability worldwide. Over the past decades, numerous studies have focused on the search for new therapies for both acute and chronic treatment, on nonpharmacological approaches and examining lifestyle factors that influence the severity of this pathology, as well as developing forecasting models for migraine attacks.[12,71] In the field of medicine, the ability to predict outcomes based on past events is of paramount significance. This can not only facilitate preventive treatment but also allows to manipulate conditions that might result in an unfavourable outcome for the patient. However, a similar approach to conditions like migraines remains lacking in many

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aspects.[44] The scope of this review is to conduct a comprehensive evaluation of data on triggers and protectors to identify the factors that might actually affect the frequency of migraine attacks. Indeed, this is one of the main challenges in developing a highly accurate forecasting model and is crucial for effective disease management, although there is still no broad agreement on protective and triggering factors.[48] In addition, the results have frequently been ambiguous, as it is not always easy to distinguish triggers from premonitory symptoms[45] and because individuals do not all respond in the same way to the same triggers.[14,49]

As a consequence, the outcomes of the most recent studies on developing forecasting models for new migraine attack onsets based on triggers and protectors are promising but necessitate further improvements to produce forecasting models with high predictive accuracy.[34,35,75] Nevertheless, the advancement in the field of machine learning (ML) has allowed research to make significant progress in prediction and forecasting[38,41] due to the ability to analyse vast amounts of retrospective data, paving the way to effective predictions.[7] Indeed, there is significant room for improvement, encompassing various aspects such as the availability of richer data sets, the consideration of multiple predictors for new onsets, the evaluation of protective factors, and the enhancement of measurement accuracy and frequency.[44,78]

This systematic review aims to collect recent studies that explore the influence of lifestyle management on the frequency of migraine attacks in adult patients with episodic migraine with and without aura. In particular, we aim at overviewing lifestyle modifications, including dietary habits, physical activity, sleep routines, and stress management. These aspects include (1) triggers that can be defined as behaviours or events associated with an increased probability of a migraine attack occurring within a relatively short latency,[45] (2) risk factors that increase the frequency of migraine attacks, and (3) protective factors that reduce it. By identifying lifestyle factors that consistently affect migraine onset, this review provides an important foundation for creating forecasting models and, consequently, digital tools, such as smartphone applications and devices, to support real-time monitoring and personalised prediction and enhance the quality of life in individuals coping with migraines. Indeed, a wealth of evidence emphasises the substantial role of a healthy lifestyle in enhancing quality of life, managing symptoms, and facilitating self-care among migraine sufferers.[32,70]

2. Methods

This systematic review was conducted in accordance with PRISMA reporting guidelines.[60] The protocol for this systematic review was registered on PROSPERO (registration number CRD42024511300). The Population, Intervention/exposure, Comparator, Outcome, and Study design (PICOS) questions were defined as follows: the population consists of adults older than 18 years affected by episodic migraine; the intervention/exposure pertains to lifestyle variables; there is no applicable comparator (N/A); the outcome is the change in the frequency or probability of the onset of migraine attacks (increase or decrease); the study design includes observational studies (prospective cohort studies, cross-sectional studies), and interventional studies (nonrandomized experimental studies, randomised clinical trials).

2.1. Search strategy

On December 2023, a systematic online bibliography search was carried out through PubMed, ScienceDirect, Google Scholar, and Scopus databases. We used the following core search terms and their combination: "forecasting," "not chronic migraine," "triggers," "protectors," and "lifestyle" (eg, (((forecasting) AND (lifestyle)) AND (migraine)) NOT (chronic)). To get a broader view of the topic, we also carried out a "snowball" search to identify additional studies by searching the reference lists of publications eligible for full-text review. The selection of relevant articles was limited to the period 2018 to 2023 to obtain information about the latest findings. The search results were collected, and duplicates were removed. Subsequently, the research strategy relied on title and abstract analysis. The full text of an article was retrieved for further investigation if the title and abstract met the inclusion criteria.

2.2. Study selection and eligibility criteria

To be considered for full-text screening, the title and abstracts of original research reports had to be written in English, focused on adults (>18 years old) with episodic migraine (ie, characterised by headaches that occur on fewer than 15 days per month), who experienced variations in attack frequency or probability of onset due to specific lifestyle factors. If a study included populations beyond those identified by the PICOS framework, this review focused solely on the results relevant to the targeted population of interest. Although meta-analyses could have been valuable for this review and therefore considered as part of the eligibility criteria, none were found that exclusively covered studies related to the population of interest. Literature reviews, animal studies, case studies, conference abstracts, and those that studied populations with concomitant headaches and comorbidities such as diagnosis of vestibular disease (eg, Menière disease, benign paroxysmal positional vertigo, or basilar migraine) were excluded. In cases where the study did not explicitly define the criterion of "episodic" in migraine diagnosis, a statistical evaluation was conducted using the data derived from the monthly days of migraine. Specifically, by considering the mean value and standard deviation, the Z-score was determined (Z-score $= [X - \mu] / \sigma$). This score was then applied to assess the probability of a subject experiencing more than 15 migraine days per month. Consequently, the studies were deemed eligible if they demonstrated an estimated percentage of at least 95% of subjects with less than 15 migraine days per month at baseline.

The lifestyle factors evaluated included dietary habits, physical activity, sleep patterns, and stress management, as these are considered the most significant in their effect on migraines according to the existing literature.[71] Given the recent COVID-19 pandemic, we have considered "quarantine," a lifestyle factor to be reviewed in conjunction with the aforementioned variables. However, in relation to this last point, we were unable to locate studies that exclusively addressed the population criteria outlined in the PICOS framework. In addition, we aimed to evaluate the effect of smoking as a lifestyle factor, but there is limited knowledge on how smoking affects migraine symptoms, and our literature search did not identify any studies meeting our eligibility criteria.

The chosen studies were later categorised according to the effect on migraine attack frequency associated with the considered lifestyle factor: if they were linked to an increase in attack frequency, they were defined as risk factors; if they led to a decrease in attack frequency, they were defined as protective factors; if they were associated with an increased probability of a migraine attack occurring within "a relatively short period,"[45] they were defined as triggers.

2.3. Risk of bias assessment

We assessed the risk of bias in the studies included in this systematic review using the JBI (Joanna Briggs Institute) Critical

Appraisal Tool,[56] adapting its specific checklists to match the types of studies under review. The checklists applied were for analytical cross-sectional studies, cohort studies, nonrandomized experimental studies, and randomised controlled trials. The JBI critical appraisal tool was developed by an international working group and approved by the JBI Scientific Committee following extensive peer review.[56] As a result of the risk of bias assessment, the studies were categorised as follows: high risk of bias (N = 1), moderately high risk (N = 1), moderate risk (N = 13), moderately low risk (N = 8), and low risk (N = 13). It is crucial to note that most studies classified as having moderate or moderately low risk did not assess the presence of confounding factors or develop a strategy to address them, which is the primary reason they were not considered to have a low risk of bias. Nevertheless, because each article provided insights into the role of lifestyle in modifying the frequency of migraine attacks, we chose to include all the studies we screened in our review.

3. Results

The PubMed, Google Scholar, and ScienceDirect search yielded 390 records, after 115 duplicates were removed; 17 records were identified through snowball search. After the titles and abstracts of all 407 records were screened according to the inclusion and exclusion criteria, 330 were excluded and 76 were found to be potentially eligible, as shown in **Figure 1**. Of 76 full-text articles, 36 studies were identified as meeting the prespecified criteria based on the consensus of at least 3 authors.

3.1. Dietary habits

Among the 36 identified studies, 18 examined dietary habits (**Table 1**). Within this group, 13 studies investigated how lifestyle factors acted as risk or protective factors. Within the subset of risk or protective factors, 6 studies evaluated the effects of specific diets,[4,8,15,20,65,77] and among them, 4 considered a starting population that was overweight or obese.[15,20,65,77] The diets valuated in these studies include the Healthy Eating Plate (HEP),[4] very low-calorie ketogenic diet (VLCKD),[15,20] 2:1 ketogenic diet,[77] low-glycemic-index diet (LGID),[77] Dietary Approaches to Stop Hypertension (DASH) and the Mediterranean diet,[8] and calorie-restricted diet combined with an exercise regimen.[65] Furthermore, 5 studies examined the variation in monthly migraine days resulting from the use of dietary supplements.[19,26,36,62,64] Specifically, they investigated the effect of exogenous ketone bodies (beta-hydroxybutyrate 6.6–7.54 g/d),[64] oral coenzyme Q10 alone (400 mg/d),[19] vitamin D3 (50 μg/d),[27] magnesium oxide (500 mg/d),[36] and oral coenzyme Q10 in conjunction with nanocurcumin (300 + 80 mg/d).[62] Two studies focused on daily water intake[37] and body mass index (BMI) value.[58] Among the 17 studies considered, 5 evaluated the trigger role of specific dietary habits: daily coffee consumption,[3,54,79] skipped meals,[16] dehydration,[16] and alcohol.[53] Of these 18 studies, only 1 did not yield statistically significant results for the parameters considered in this review.[64] **Table 1** provides more details.

3.2. Physical activity

Among the 36 studies identified, 7 focused on examining physical activity as a protective (**Table 2**). Specifically, physical exercise was considered in various forms, including yoga,[39,52] tai chi,[82] regular exercise,[16] aerobic exercise,[59] and high-intensity training.[31,33] These 7 studies yielded statistically significant results in reducing the frequency of migraine attacks, with the exception of 1 variable in 1 study (ie, moderate continuous training).[33] Three of the 6 studies assessed physical exercise in combination with

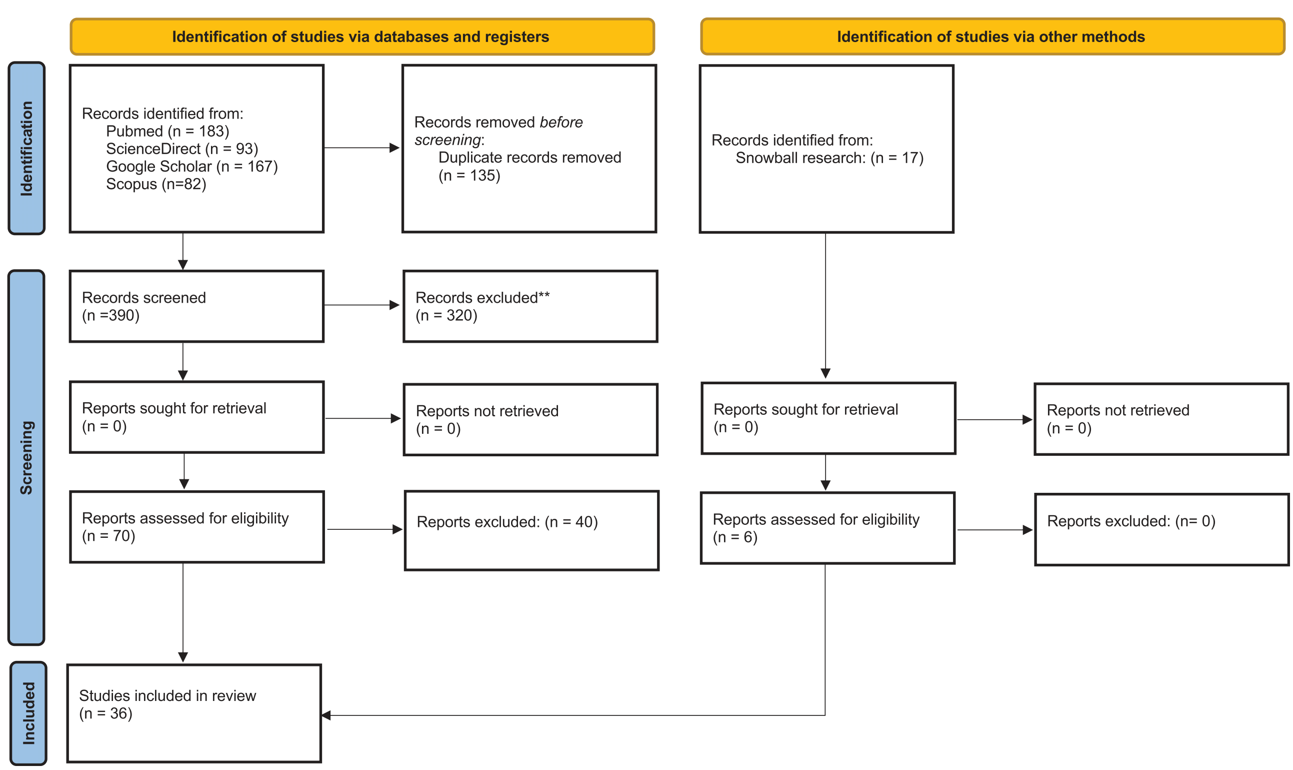

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram.[60]

Table 1

Studies investigating the role of *dietary habits* as protective factor, risk factor, or trigger.

Author	Year	Type of study	Lifestyle factor	Effect	Duration of observation	Population size, age (mean ± SD), male:female ratio
Alstadhaug et al	2020	Randomised crossover trial	Coffee withdrawal	Trigger ($P < 0.05$)	14 wk	10, 46.3 ± 9.9 y, 1:9
Altamura et al	2020	Interventional study	Diet: healthy eating plate (HEP) education	Protective factor: significant frequency reduction ($P = 0.004$)	24 wk	97, 42.08 ± 12.93 y, 1.83:10
Bakırhan et al	2022	Cross-sectional study	Diet: DASH and mediterranean diet	High DASH score risk factor: significant frequency increase ($P = 0.005$); Mediterranean diet nonsignificant effect	3 mo	80, 34.0 ± 9.02 (male) 35.7 ± 9.72 (female) y, 2.5:10
Caprio et al	2023	Randomised controlled trial	Diet: very-low-calorie ketogenic diet	Protective factor: significant frequency reduction ($P = 0.008$)	24 wk	57, 42.6 ± 11.5 y, 0.54:10
Casanova et al	2023	Prospective cohort study	Coffee consumption, alcohol consumption, missed meals, dehydration	Coffee protective factor in 10% of the population; alcohol protective factor in 6.7%; missed meals trigger in 7.1%; dehydration trigger in 7.4%	6 y and 4 mo	1125, 43.1 ± 12.7 y, 1.36:10
Dahri et al	2019	Randomised controlled trial	Diet supplementation: oral coenzyme Q10 (coQ10)	Protective factor: significant frequency reduction ($P = 0.018$)	4 mo	45, 32.35 ± 6.60 (CoQ10 group) 32.32 ± 7.52 (placebo group) y, 0:10
Di lorenzo et al	2019	Randomised cross-over trial	Diet: very-low-calorie ketogenic diet	Protective factor: significant frequency reduction ($P < 0.0001$ respect to nonketogenic diet)	20 wk	35, 43 ± 10 y, 2.07:10
Ghorbani et al	2020	Randomised controlled trial	Diet supplementation: Vit. D3	Protective factor: significant frequency reduction ($P = 0.031$)	12 wk	74, 37 ± 8 (vitamin D3 group) 38 ± 12 (placebo group) y, 1.56:10
Karimi et al	2021	Randomised crossover trial	Diet supplementation: magnesium oxide	Protective factor: significant frequency reduction ($P < 0.001$)	16 wk	70, 36.78 ± 8.85 y, 1.48:10
Khorsha et al	2020	Cross-sectional observational study	Adequate water intake	Protective factor: significant frequency reduction ($P < 0.001$)	1 mo	256, 34.3 ± 7.9 y, 0:10
Mostofsky et al	2019	Prospective cohort study	Coffee consumption	Trigger (>3 coffee/day (P-quadratic trend $= 0.024$)	6 wk	98, 35.1 ± 12.1 y, 1.40:10
Mostofsky et al	2020	Prospective cohort study	Alcohol consumption	Trigger (>5 servings/day) ($P = 0.03$)	6 wk	98, 35.1 ± 12.1 y, 1.40:10
Ojha et al	2018	Cross-sectional study	Obesity	Risk factor: significant frequency increase ($P = <0.05$)	N/A	168, 32.7 ± 9.9 y, 0:10
Parohan et al	2021	Randomised controlled trial	Diet supplementation: oral coenzyme Q10 and nano curcumin	Protective factor: significant frequency reduction ($P < 0.001$)	8 wk	100, 33.60 ± 8.65 (nano curcumin group) 32.05 ± 9.02 (CoQ10 group) 31.70 ± 8.87 (nano curcumin and CoQ10) y, 31.75 ± 9.43 (placebo group), 3.70:10
Putananickal et al	2022	Randomised cross-over trial	Diet supplementation: exogenous ketone bodies	Nonsignificant effect ($P = 0.578$)	36 wk	40, 35.15 ± 10.92 y, 0.87:10
Razeghi jahromi et al	2018	Interventional study	Diet: weight loss in obese patients	Protective factor: significant increase in number of migraine-free d ($P < 0.001$)	6 mo	26, 42.23 ± 9.03 y, 0:10
Tereshko et al	2023	Retrospective longitudinal study	Diet: 2:1 ketogenic diet, low-glycemic-index diet	Protective factor: significant frequency reduction (2:1 ketogenic diet $P = 0.022$; low-glycemic-index diet $P < 0.001$)	6 mo	27
Turner et al	2019	Prospective cohort study	Coffee consumption (surprise*); alcohol consumption (surprise)	Trigger ($P < 0.001$)	Between 11 and 96 d (mean: 49 d)	95, 40.3 ± 12.9 y, 2.58:10

* Surprise i.e. "the rarity or unexpectedness of the trigger in relation to past exposures"[79].
DASH, dietary approaches to stop hypertension.

prophylactic pharmacological therapy.[31,39,52] **Table 2** provides detailed information.

3.3. Stress management

In the pool of 36 identified studies, 4 targeted the evaluation of perceived stress as a trigger[16,79] or risk factor[5,80] (**Table 3**). Conversely, 7 studies delved into how managing stress through specific cognitive therapies could act as a protective factor, potentially reducing the frequency of migraines each month. The cognitive therapies considered in these studies include Mindfulness-Based Stress Reduction (MBSR),[68,72] Mindfulness-Based Cognitive Therapy for Migraine (MBCT-M),[69,73] and Acceptance and Commitment Therapy.[28–30] Two

Table 2

Studies investigating the role of *physical activity* as protective factor.

Author	Year	Type of study	Lifestyle factor	Effect	Duration of observation	Population size, age (mean ± SD), male:female ratio
Casanova et al	2023	Prospective cohort study	Physical activity	Protective factor in 10.9% of the population	6 y and 4 mo	1125, 43.1 ± 12.7 y, 1.36:10
Hagan et al	2020	Prospective cohort study	Physical activity: moderate-vigorous exercise	Protective factor: significant frequency reduction ($P = 0.001$)	6 wk	94, 34.3 ± 11.4 y, 1.49:10
Hanssen et al	2018	Randomised controlled trial	Physical activity: high-intensity interval training (HIT) and moderate continuous training (MCT)	HIT protective factor: significant frequency reduction (standardised mean difference [90% CI] −0.28 [−0.58; 0.02]); MCT no significative effect	16 wk	36, 36.2 ± 10.7 (HIT group) 37.0 ± 8.7 (MCT group) 37.3 ± 11.9 (control group) y, 2.41:10
Kumar et al	2020	Randomised controlled trial	Physical activity: yoga	Protective factor: significant frequency reduction ($P < 0.0001$)	3 mo	160, 30.5 ± 8.01 (yoga group) 31.9 ± 8.17 (control group) y, 4.44:10
Mehta et al	2021	Randomised controlled trial	Physical activity: yoga and physical therapy	Protective factor: significant frequency reduction ($P < 0.005$)	3 mo	61, 39.15 ± 8.24 (physical therapy group) 34.3 ± 9.57 (yoga group) 36.81 ± 10.85 (control group) y, 3.51:10
Oliveira et al	2019	Randomised controlled trial	Physical activity: aerobic exercise	Protective factor: significant frequency reduction ($P < 0.01$)	20 wk	58, 36.2 ± 10.9 y, 2.24:10
Xie et al	2022	Randomised controlled trial	Physical activity: tai chi	Protective factor: significant frequency reduction ($P < 0.01$)	24 wk	73, 50.9 ± 10.2 (tai chi group) 47.1 ± 11.8 (control group) y, 0:10

Table 3

Studies investigating the role of *stress management* as protective factor, risk factor, or trigger.

Author	Year	Type of study	Lifestyle factor	Effect	Duration of observation	Population size, age (mean ± SD or 95% CI), male:female ratio
An et al	2019	Cross-sectional study	Stress	Risk factor: significant frequency increase, only in male population ($P < 0.05$)	N/A	447, 38.4 ± 11.5 (low-frequency episodic migraine group) 36.0 ± 11.4 (medium-frequency episodic migraine group) 36.6 ± 11.9 (high-frequency episodic migraine group) 38.2 ± 10.9 (control group) y, 3.92:10
Casanova et al	2023	Prospective cohort study	Stress	Trigger in 15%, 7% of the population	6 y and 4 mo	1125, 43.1 ± 12.7 y, 1.36:10
Grazzi et al	2019	Randomised clinical trial	Acceptance and commitment therapy	Protective factor: frequency reduction	3 mo	24
Grazzi et al	2020	Randomised controlled trial	Acceptance and commitment therapy	Protective factor: frequency reduction	6 mo	40, 42.1 ± 11.6 (acceptance and commitment therapy group) 5.7 ± 9.7 (erenumab group) 41.8 ± 11.1 (control group) y
Grazzi et al	2021	Randomised controlled trial	Acceptance and commitment therapy	Protective factor: significant frequency reduction ($P = 0.007$)	1 y	25, 43.5 (38.2–48.8) (acceptance and commitment therapy group) 42.0 (36.5–47.5) (control group) y
Seminowicz et al	2020	Randomised clinical trial	Mindfulness-based stress reduction (MBSR+)	Protective factor: significant frequency reduction ($P = 0.004$)	1 y	98, 36 median y, 1.01:10
Seng et al	2021	Randomised clinical trial	Mindfulness-based cognitive therapy for migraine (MBCT-M)	Nonsignificant effect ($P = 0.787$)	4 mo	29, 38.6 ± 14.7 y, 0.74:10
Simshäuser et al	2020	Randomised controlled trial	Mindfulness-based stress reduction (MBSR)	Nonsignificant effect ($P = 0.07$)	13 mo	61, 43.8 ± 7.82 (MBSR group) 43.9 ± 11.1 (control group) y, 1.27:10
Simshäuser et al	2022	Randomised controlled trial	Mindfulness-based cognitive therapy for migraine (MBCT-M)	Protective factor: Significant frequency reduction ($P = 0.04$)	10 mo	54, 44.4 ± 8.86 (MBCT-M group) 46.1 ± 12.11 y, 1.27:10
Turner et al	2019	Prospective cohort study	Stress (surprise)	Trigger ($P < 0.001$)	Between 11 and 96 d (mean: 49 d)	95, 95, 40.3 ± 12.9 y, 2.58:10
Vgontzas et al	2021	Prospective cohort study	Stress	No significant effect (HR 1.12, 95% CI 0.93, 1.35)	6 wk	98, 35.1 ± 12.1 y, 1.36:10

Table 4

Studies investigating the role of *sleep* as protective factor, risk factor, or trigger.

Author	Year	Type of study	Lifestyle factor	Effect	Duration of observation	Population size, age (mean ± SD), male:female ratio
Bertisch et al	2020	Prospective cohort study	Sleep fragmentation, short sleep duration, low sleep quality	Sleep fragmentation trigger (OR 1.39, 95% CI 1.07–1.81); no significant effect for short sleep duration and low sleep quality	42 d	98, 35.1 ± 12.1 y, 1.40:10
Casanova et al	2023	Prospective cohort study	Sleep refreshed, regular sleep duration, high sleep quality	Sleep refreshed protective factor in 33.8% of the population, regular sleep duration in 7.1%, high sleep quality 17.9%	6 y and 4 mo	1125, 43.1 ± 12.7 y, 1.36:10
Song et al	2018	Observational cross-sectional study	Short sleep duration, poor sleep quality	Risk factor: short sleep duration significant frequency increase ($P = 0.048$), poor sleep quality ($P = 0.009$)	3 mo	143, 3.36:10
Vgontzas et al	2021	Prospective cohort study	Poor sleep quality	Risk factor: significant frequency increase (HR 1.22, 95% CI 1.02, 1.46)	6 wk	98, 98, 35.1 ± 12.1 y, 1.36:10
Yoo et al	2023	Longitudinal observational study	Good multidimensional sleep health	Protective factor: significant frequency reduction (95% confidence interval: 0.9, 5.7	6 wk	98, 34.9 ± 11.6 (sleep health score <3 group) 35.1 ± 12.2 (sleep health score ≥3 group) y, 1.40:10

of these studies assessed stress management techniques in combination with pharmacological therapy.[28,72] Among the 11 studies, 3 did not yield statistically significant results for the parameters considered in this review[69,72,73]; 1 study yielded significant results only in the male population.[5] **Table 3** provides more details.

3.4. Sleep

Among the 36 identified studies, 5 focused on exploring the role of sleep and its various attributes as trigger, risk factor, and protective factor (**Table 4**). In particular, 1 study identified sleep fragmentation as a statistically significant trigger, whereas findings regarding short sleep duration and low sleep quality lacked significance in their results.[11] Furthermore, 2 studies delved into specific sleep characteristics as risk factors, finding both insufficient sleep duration[74] and poor sleep quality[74,80] to be significant, especially when associated with moderate/high stress.[80] In the realm of protective factors, 2 studies have highlighted the importance of healthy sleep attributes.[16,84] One study distinctly found that overall good multidimensional sleep health, rather than individual sleep dimensions, is linked to reduced migraine attack frequency.[84] Another study emphasises that factors such as high sleep quality, sufficient sleep duration, and particularly the sensation of waking up refreshed act as protective factors.[16] **Table 4** provides more details.

4. Discussion

This systematic review has investigated the effect of lifestyle on migraine frequency, identifying factors that may either alleviate or exacerbate patient symptoms. The findings support incorporating lifestyle changes in migraine management, emphasizing their crucial role in enhancing patient well-being. Importantly, these insights contribute to migraine forecasting by clarifying which lifestyle factors consistently influence attack frequency and identifying those with more inconsistent results, which may require further investigation before inclusion in predictive models. This aspect gains further significance when considering recent scientific research on migraine triggers that often shows lack of consistency and high interindividual variability. Notably, investigations into classic triggers like chocolate[57] or tobacco consumption[76] have become less frequent, largely due to the nonsignificant correlations found between these factors and migraine triggers in the majority of cases. Considering the substantial interindividual variability in susceptibility to triggers, as highlighted by Casanova et al.,[16] it is increasingly evident that new forecasting models should exhibit adaptability and, to a certain extent, be customised for each individual. An intriguing perspective on triggers like coffee, stress, and alcohol emerged from a study conducted by Turner et al..[79] This perspective emphasised that a trigger's ability to precipitate a migraine attack is not solely determined by the patient's exposure to the trigger itself. Instead, it hinged on the concept of "surprise," as defined by Turner and colleagues, which refers to the rarity or unexpectedness of the trigger in relation to past exposures. This study thus presents one of the potential avenues for incorporating triggers into forecasting models. Smoking was one of the lifestyle factors whose effect we wanted to evaluate; however, limited knowledge exists on how smoking affects migraine symptoms. Despite cigarette smoking appeared to be more prevalent in individuals with migraine as compared with the general population, yet the nature of this connection remains ambiguous.[81] Considering on a wide basis the outcomes of this review, it should be taken into account that the temporal span of the included studies encompasses the period affected by the SARS-Cov2 pandemic. This could have influenced subsequent alterations to daily habits, thus introducing a potential confounder in the findings. However, given the case–control design of the majority of articles, we are confident that the putative bias has been at least partially controlled. One limitation of the systematic review is the diversity of study designs among the included studies, which complicates the comparison of results. The varying methodologies across these studies introduce a level of heterogeneity that challenges the synthesis of findings and the drawing of conclusive insights. Consequently, there is a clear need for further research that adheres to more standardised and rigorous methodologies, such as randomised controlled trials.

4.1. Dietary habits

Research examining the effects of specific diets on migraine attack frequency has yielded promising results. Notably, these benefits are more pronounced in overweight or obese patients, reinforcing the increasingly recognized theory of a correlation between obesity and migraine, potentially mediated by inflammatory mechanisms in adipose tissue and strictly linked to altered superior functions.[17,25,27] Studies focusing on ketogenic diets have shown particularly positive outcomes.[15,20,77] These findings contribute to an expanding corpus of evidence underscoring the effectiveness of this diet not only for migraine sufferers but also in treating a variety of neurological conditions.[21,63] Of the 3 studies reviewed, 2 included a baseline population that was overweight or obese, and the ketogenic diet used was the VLCKD,[15,20] which led to both a decrease in BMI and a reduction in migraine attack frequency. This aspect might raise the question of whether the reduction in attack frequency is primarily due to weight loss rather than the ketogenic diet itself. However, the study design, which compared the group following the ketogenic diet (VLCKD) with groups following other hypocaloric diets (ie, hypocaloric balanced diet[15] and very-low-calorie nonketogenic diet[20]), allows for identifying a specific role of the ketogenic component in reducing attack frequency, independent of the BMI decrease observed in all groups regardless of the diet followed. In addition, in the third study reviewed,[77] the 2:1 ketogenic diet, which significantly reduced migraine attack frequency, was followed by individuals with a normal BMI (18.5–24.9 kg/m^2), further suggesting a specific role of the ketogenic diet in decreasing migraine frequency. This should not be surprising, considering that ketogenic diets appear to antagonise some of the underlying pathophysiological mechanisms of migraines, like abnormal excitability,[10,18,47] brain metabolism,[23] and counteracting neuroinflammation and redox mechanisms.[9,24]

Research on dietary supplements, such as magnesium,[36] vitamin D3,[26] and oral coenzyme Q10,[19,62] consistently reveals a decrease in the frequency of migraine attacks, positioning them as protective factors. This improvement is likely attributable to their antioxidant, anti-inflammatory, and bioenergetic properties.[6,51] Consequently, these supplements emerge as important prophylactic therapeutic options and also have a role in the realm of migraine forecasting.

More broadly, the collective findings of these studies about dietary habits emphasise the importance of proper dietary habits in managing migraine. These include avoiding skipped meals,[16] ensuring adequate water intake,[16,37] and maintaining a low or stable caffeine consumption.[3,54,79] These factors are crucial in the lifestyle management of individuals suffering from migraines, as they have been shown to effectively reduce the frequency of attacks.[66] Concerning alcohol consumption, recent research indicates an unclear relationship between alcohol intake and the onset of migraine attacks. Mostofsky et al.[53] have provided evidence suggesting that although 1 to 2 servings of alcoholic beverages do not typically act as triggers for migraines, consumption of 5 or more servings appears to have a triggering effect. Thus, there is no evidence to discourage the consumption of small doses of alcohol in migraine patients.[61] The role of coffee consumption in migraine research is significant due to its dual capacity to both alleviate acute symptoms and potentially serve as a trigger.[85] Recent studies indicate that migraine patients should aim to keep their daily caffeine intake consistent and moderate. This recommendation stems from findings that both caffeine withdrawal[3] and excessive consumption (>3 coffee/day) [55] can precipitate migraine attacks.

4.2. Physical activity

The studies on physical activity featured in this review, encompassing yoga,[39,52] tai chi,[82] and high-intensity interval training,[33] have consistently demonstrated a reduction in the frequency of migraine attacks. These data are particularly relevant considering that most of the studies evaluated in this review are RCTs and therefore the result of rigorous assessments. This underscores the importance of incorporating physical activity into the lifestyle of patients suffering from migraines. In addition, these studies highlight a potentially significant role in developing forecasting models for migraine attacks. Physical activity is also critical when considering its synergistic effect with other lifestyle aspects. It can potentially lead to a reduction in BMI, a decrease in perceived stress,[55] and an improvement in sleep quality.[55,83] These findings align with the latest guidelines[40] that assign a "grade B" recommendation to aerobic exercises, moderate-continuous aerobic exercise, and yoga, for reducing the frequency, duration, and intensity of pain, as well as for improving the quality of life in patients with migraine.

4.3. Stress and stress management

Stress has long been associated with migraine and is considered by many to be a trigger.[50] However, similar to other commonly recognized triggers, stress demonstrates significant interindividual variability and sometimes inconsistency in its association with the onset of a migraine attack.[5,16,79,80] In the previously mentioned study by Turner et al.,[79] perceived stress levels become a more reliable trigger when they deviate from an individual's usual level. As a result, not only increases but also reductions in stress relative to an individual's norm can act as triggers. This result aligns with the onset of the phenomenon known as "let-down headache," typical of migraine patients.[42]

In any case, the management of stress through behavioural therapies is a valid strategy in addressing migraine symptoms, showing a "grade A" level of evidence.[1] This review evaluated studies on mindfulness-based therapies and acceptance and commitment therapy, both active research areas with growing evidence supporting their use in migraine treatment. The studies on mindfulness-based therapies in particular present a complex picture. Although most studies reviewed were randomised controlled trials (RCTs), their results varied: some demonstrated a significant reduction in migraine days,[68,73] comparable to commonly used first-line treatments for episodic migraine prevention, whereas others did not show a meaningful decrease.[69,72] Nonetheless, even in these cases, there was a significant improvement in headache-related disability. Further studies are needed to clarify this factor's role as a protective measure against migraine onset, as current evidence is insufficient to reliably include it in forecasting models. Regarding the studies in this review on Acceptance and Commitment Therapy, the findings are more consistent, demonstrating a significant homogeneous reduction in the frequency of migraine attacks.[28–30] Thus, Acceptance and Commitment Therapy emerges as a potential addition to the development of forecasting models, especially if its role as a protective factor is further supported by additional research.

4.4. Sleep

The association between sleep disturbances and the onset of migraine attacks has been extensively documented,[2] and the current scientific literature views this interaction as bidirectional.[22] In addition, sleep quality is also influenced by other lifestyle-related aspects. For instance, when examining sleep disorders linked to obesity, like obstructive sleep apnea, the complex interplay of these conditions becomes evident. However, the studies included in this review highlight the multifaceted nature of sleep evaluation, and the overall picture that emerges is complex and not straightforward to assess. Although all studies generally indicate that sleep disturbances may increase the frequency of attacks and that multidimensional sleep health could act as a protective factor, the individual components of sleep yield inconsistent or often nonsignificant results.[84] Therefore, maintaining good sleep hygiene, especially in the long term rather than occasionally, emerges as a key goal in the lifestyle management of patients with migraines. On this topic, it is worth noting that the study by Vgontsas defines that poor sleep quality on a given day is not associated with immediate headache, but having poor sleep quality over the last month is associated with a higher migraine burden over the next 6 weeks, highlighting that it is a risk factor rather than a trigger.[80] Developing a predictive model for migraines presents the challenge of integrating individual sleep characteristics as variables, particularly in the absence of additional studies that could more precisely clarify their potential role as triggers. Nonetheless, it appears viable to include an overall assessment of sleep in such a model, adopting a holistic approach to this variable. In light of the studies analysed, it is important to consider more homogeneous approaches in future research, ideally using RCTs as the study design, to allow for more valid comparisons of the results obtained.

5. Conclusion

This systematic review has comprehensively examined the role of lifestyle management in influencing the frequency of migraine attacks among adults with episodic migraine. The substantial body of evidence gathered here highlighted the effect of lifestyle factors not only on the frequency of attacks but also on the overall symptomatology and pain management.

In clinical practice, guiding patients toward appropriate lifestyle modifications is crucial. Here is a list of the main recommendations gathered in this review:

- Dietary habits:
  - Maintaining healthy eating habits is crucial, including avoiding meal skipping, staying well-hydrated, and keeping a healthy weight.
  - Specific dietary approaches, like the ketogenic diet, have shown to be effective in reducing migraine frequency.
  - Incorporating dietary supplements, such as oral coenzyme Q10, may help lower the occurrence of migraine attacks.
  - From a migraine management perspective, alcohol intake should be limited to 1 to 2 servings, as this amount does not appear to act as a migraine trigger.
  - For regular coffee drinkers, maintaining a consistent and moderate daily caffeine intake is recommended, as both caffeine withdrawal and excessive intake (more than 3 cups per day) can increase the likelihood of migraine attacks.
- Physical activity: Various types of physical activity, from yoga to moderate-to-vigorous exercise, consistently appear to reduce the frequency of migraine attacks.
- Stress management: Techniques such as mindfulness and Acceptance and Commitment Therapy are valuable tools for symptom relief; however, further research is needed to clarify their effect on migraine frequency and, consequently, their integration into forecasting models for migraine onset.
- Sleep: Maintaining good sleep hygiene, particularly as a long-term habit rather than an occasional practice, is a key goal in migraine management, as it appears to reduce attack frequency. However, further research is needed to reliably integrate individual sleep characteristics, such as duration and fragmentation, into forecasting models.

A crucial takeaway from this review was the necessity of tailoring forecasting models to individual patients. It becomes evident that not just the exposure to specific triggers, such as stress, but deviations from an individual's usual exposure levels might precipitate migraine attacks. Additional analyses, using mathematical models that incorporate the findings of this review, could serve as the foundation for developing an effective forecasting model. Given its widespread accessibility, a smartphone app where patients can directly enter specific data related to their physical activity and dietary habit, combined with a wearable device capable of monitoring physiological parameters as well as sleep quality and stages, would be an ideal solution to enable patients to benefit from a lifestyle-based forecasting model for migraine attacks. This application could identify specific patterns associated with an increased or decreased risk of migraine onset, focusing exclusively on lifestyle factors demonstrated by scientific literature to significantly affect migraine frequency. Furthermore, the continuous feedback collected through the app would allow the algorithm to progressively adapt to each individual, accounting for significant interindividual variability, especially concerning migraine triggers. Beyond data collection and generating predictive algorithms, the app could also serve as a tool to promote behavioral changes that actively contribute to preventing or reducing migraine attacks.

Although this review was centred on episodic migraine, it is plausible that the risk factors discussed could play a significant role in the long-term evolution of migraine's pathophysiology, possibly leading to a shift from episodic to chronic forms.[43] This concept, articulated also by Buse et al., suggests that during the progression from episodic to chronic migraine, certain risk factors may be intricately linked to a progressively sustained activation of the trigeminovascular pathway.[13] In conclusion, this systematic review underscores the importance of tailoring lifestyle modifications in migraine management, notably in their potential to reduce attack frequency. Such models should be designed with a precision medicine approach, ensuring that they are customised to the unique genetic and environmental of each patient.

Disclosures

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