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REVIEW ARTICLE

Efficacy of various exercise interventions for migraine treatment: A systematic review and network meta-analysis

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Abstract

Objective: To compare various exercise modalities' efficacy on migraine frequency, intensity, duration, and disability.

Background: Exercise has been shown to be an effective intervention to reduce migraine symptoms and disability; however, no clear evidence exists regarding the most effective exercise modalities for migraine treatment.

Methods: A systematic review was performed in PubMed, PEDro, Web of Science, and Google Scholar. Clinical trials that analyzed the efficacy of various exercise modalities in addressing the frequency, intensity, duration, and disability of patients with migraine were included. Eight network meta-analyses based on frequentist (F) and Bayesian (B) models were developed to estimate the direct and indirect evidence of various exercise modalities. Standardized mean difference (SMD) and 95% confidence (CI) and credible intervals (CrI) were calculated for each treatment effect based on Hedge's *g* and *p* scores to rank the modalities.

Results: We included 28 studies with 1501 migraine participants. Yoga (F: SMD −1.30; 95% CI −2.09, −0.51; B: SMD −1.33; 95% CrI −2.21, −0.45), high-intensity aerobic exercise (F: SMD −1.30; 95% CI −2.21, −0.39; B: SMD −1.17; 95% CrI −2.20, −0.20) and moderate-intensity continuous aerobic exercise (F: SMD −1.01; 95% CI −1.63, −0.39; B: SMD −1.06; 95% CrI −1.74, −0.38) were significantly superior to pharmacological treatment alone for decreasing migraine frequency based on both models. Only yoga (F: SMD −1.40; 95% CI −2.41, −0.39; B: SMD −1.41; 95% CrI −2.54, −0.27) was significantly superior to pharmacological treatment alone for reducing migraine intensity. For diminishing migraine duration, high-intensity aerobic exercise (F: SMD −1.64; 95% CI −2.43, −0.85; B: SMD −1.56; 95% CrI −2.59, −0.63) and moderate-intensity continuous aerobic exercise (SMD −0.96; 95% CI −1.50, −0.41; B: SMD −1.00; 95% CrI −1.71, −0.31) were superior to pharmacological treatment alone.

Abbreviations: CI, confidence interval; CrI, credible interval; GRADE, Grading of Recommendations, Assessment, Development, and Evaluation; I^2, inconsistency index; NMA, network meta-analysis; PEDro, Physiotherapy Evidence Database; RCT, randomized controlled trial; SMD, standardized mean difference; T^2, tau square; VAS, visual analog scale.

Conclusion: Very low-quality evidence showed that yoga, high- and moderate-intensity aerobic exercises were the best interventions for reducing migraine frequency and intensity; high- and moderate-intensity aerobic exercises were best for decreasing migraine duration; and moderate-intensity aerobic exercise was best for diminishing disability.

Plain Language Summary: Exercise can help improve migraine, but we wanted to know if certain types of exercise are most helpful. We looked at data from many studies that explored different types of exercise for migraine, and we found that people who did moderate-intensity aerobic exercise had fewer and less severe migraine symptoms. Yoga and higher-intensity exercise were also helpful in some studies, but more research is needed to help doctors make the best exercise recommendations for their patients.

KEYWORDS
disability, migraine disorders, migraine symptoms, networking meta-analysis, therapeutic exercise

INTRODUCTION

The complexity and high prevalence of migraine, coupled with the elevated cost of work absenteeism and healthcare assistance, have propelled the development of various pharmacological interventions.[1–4] Non-steroidal anti-inflammatory drugs, triptans, antiseizure medications, antidepressants, calcitonin gene-related peptide pathway monoclonal antibodies, ditans, gepants, and onabotulinumtoxinA have shown efficacy in halting migraine episodes and decreasing migraine frequency[5–9]; however, their effectiveness varies among patients and the short- and long-term adverse effects they produce can decrease the health status and quality of life of patients with migraine.[6–10]

Other non-pharmacological interventions, such as exercise interventions, have been studied to diminish the need for medication.[11,12] Exercise has been shown to decrease the frequency, intensity, and duration of migraine symptoms, as well as disability, and to improve quality of life.[11,12] Moreover, it could reduce medication intake and improve general health in the population, which could dampen some adverse effects of pharmacological interventions.[13,14] Alongside these benefits, physical activity and exercise can also influence psychosocial factors such as anxiety and depressive symptoms, as well as social relationships, improving migraine symptoms and disability.[15,16]

Various exercise modalities have been studied, the most researched and recommended being yoga and aerobic exercise,[17] but there is no clear consensus on which interventions are superior for decreasing migraine frequency, intensity, duration, and disability, based on quantitative data. A previous network meta-analysis (NMA) performed by Woldeamanuel and Oliveira[18] showed that strength training could be superior to aerobic exercise for decreasing migraine frequency; however, some exercise modalities that have been studied were not included in this article; some categorizations and outcome measures were ambiguous; the main control category, labeled as placebo, encompasses diverse interventions; and the effects on pain intensity, migraine attack duration, and disability were not studied.[19]

Following the exercise modality categorization presented in the clinical practice guideline for exercise prescription in migraine developed by La Touche et al.,[17] we conducted a NMA. The main objective was to analyze and compare various exercise modalities' efficacies on migraine frequency, intensity, duration, and disability in patients with migraine compared with standard pharmacological treatment alone. Moreover, we compared the exercise modalities with each other to determine which were superior.

METHODS

Protocol and registration

The present systematic review and NMA was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis Network Meta-analysis Extension Statement.[20] It was also registered in the International Prospective Register of Systematic Reviews (PROSPERO: CRD42023399242).

Search strategy

Two independent reviewers conducted the same search strategy in four different databases with no language or time restrictions: MEDLINE (PubMed), Physiotherapy Evidence Database (PEDro), Web of Science, and Google Scholar. The search strategy combined medical subject headings and non-medical subject headings terms, including "Migraine Disorders" and "Exercise" as the most important terms (Supplementary Material S1). Discrepancies among reviewers were resolved through consensus with the intervention of a third reviewer. The reference sections of original studies were manually screened. The initial search was performed in April 2023 and the last was in May 2023.

Eligibility criteria

Inclusion and exclusion criteria were determined based on the population, intervention, comparator, outcome measure, and study design strategy.[21] Included studies were clinical trials whose sample was aged ≥18 years, had episodic or chronic migraine, and was diagnosed by a physician. Interventions were the exercise modalities defined in the study by La Touche et al.[17]: moderate-intensity continuous aerobic exercise, high-intensity aerobic exercise, yoga, resistance training, relaxation exercise, aerobic exercise with lifestyle recommendations, aerobic and relaxation exercise, and Tai Chi. Comparators were other exercise modalities, usual care, pharmacological treatments, or education. Outcome measures were migraine frequency, intensity, duration, and disability, and they needed to be measured at the end of the intervention protocol. Migraine frequency needed to be defined as days with migraine per month, migraine attacks per month, or other similar definitions. Migraine intensity was evaluated with a visual analog scale, numeric pain rating scale, or other similar tools. Migraine duration was measured as the hours or minutes per migraine attack or other similar forms. Disability had to be assessed through validated questionnaires, such as the Headache Impact Test 6 or the Migraine Disability Assessment Test.

Selection criteria and data extraction

Two independent reviewers conducted the data analysis through the examination of the title, abstract, and keywords. If there was not enough information, a full-text review was performed. A full-text analysis was completed in the next stage to include studies that met the inclusion criteria. If any discrepancies emerged, they were resolved through consensus with a third reviewer. For data extraction, the most relevant information regarding population characteristics, interventions, comparators, outcome measures, and main results was obtained from each study and described in the results section and in a summary table. When necessary, researchers from the original studies were contacted to obtain or confirm data, especially statistical information.

Methodological quality and risk of bias assessment

The methodological quality of the included clinical trials was assessed by two independent reviewers with the PEDro scale, a validated tool for this purpose.[22] This instrument is composed of 11 items: (1) eligibility criteria; (2) random allocation; (3) allocation concealment; (4) baseline similarities between groups; (5) blinding of participants; (6) blinding of therapists; (7) blinding of assessors; (8) <15% dropouts; (9) all the patients for whom outcome measures were available received their allocated intervention or data were analyzed by "intention to treat"; (10) the statistical results of between-group comparisons were available; and (11) the point measures and measures of variability were reported. The first item was not considered for the total score because it evaluates the external validity. If the response to an item was "Yes," it obtained 1 point, and if it was "No" it obtained 0 points. The final rating was considered "poor" (0–3 points), "fair" (4–5 points), "good" (6–8 points), or "excellent" (9–10 points).[23]

The risk of bias was evaluated by two independent reviewers with the Risk of Bias 2.0 tool, a validated instrument to assess the features of trial design, conduct, and reporting through five domains: (i) randomization process; (ii) deviations from the intended intervention; (iii) missing outcome data; (iv) outcome measurement; and (v) selection of the reported result. A series of questions evaluated each domain with five possible answers: "yes," "probably yes," "probably no," "no," or "no information." Depending on the answers, an algorithm judges the risk of bias for each domain and classifies the final judgment as "low risk," "some concerns," or "high risk."[24]

The concordance between both independent reviewers in the evaluation of the methodological quality and the risk of bias was evaluated with the kappa coefficient (κ). The level of concordance was considered low if $\kappa < 0.5$, moderate if $\kappa = 0.5–0.7$, and high if $\kappa > 0.7$.[25] Any disagreement on an item that arose during this process was resolved by a third reviewer.

Qualitative analysis

Two independent reviewers used the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) tool, adapted for NMAs to classify the effects of various interventions in each outcome measure into four levels of evidence: (i) high quality: very confident that the true effect lies close to that of the estimate of the effect; (ii) moderate quality: moderately confident in the effect estimate; (iii) low quality: confidence in the effect estimate is limited; (iv) very low quality: very little confidence in the effect estimate.[26,27] This evaluation was made according to five domains: study design, imprecision, indirectness, inconsistency, and publication bias.[28] The adaptation for NMAs includes in these domains the key role of indirect comparison, the contribution of direct evidence to the estimated effect size, the importance of the transitivity assumption to the validity of the NMA, and the disagreement between direct and indirect evidence.[26] The study design domain was downgraded by 1 point if studies presented some concerns and by 2 points if they presented a high risk of bias. Imprecision was downgraded by 1 point if the confidence interval (CI) was wide and by 2 points if it crossed the non-significant limit. Indirectness was considered when the transitivity assumption could be at risk due to differences between study designs. Inconsistency was downgraded by 1 point if the designs presented heterogeneity within-design or inconsistency between-designs and by 2 points if they presented both heterogeneity and inconsistency or if it was not possible to calculate heterogeneity. Finally, the publication bias domain was downgraded if the funnel plot and Egger's regression test indicated asymmetry and a significant risk of publication bias.

Statistical analysis

Two NMAs for each outcome measure were performed based on frequentist and Bayesian methods in RStudio (RStudio, PBC, Boston, MA, USA) version 2023.06.0-431, employing R software version 4.3.1. The frequentist model was developed with the "netmeta" package (https://cran.r-project.org/web/packages/netmeta/index.html) and the "gemtc" package (https://CRAN.R-project.org/package=gemtc) for the Bayesian model. For this purpose, we used the online guide developed by Harrer et al.[29] Exercise interventions were categorized based on their comparability according to the study of La Touche et al.[17] Their effects on migraine frequency, intensity, duration, and disability were analyzed. Direct comparisons between exercise modalities for each variable were represented with a network graph.

The standardized mean difference (SMD) for each treatment's comparison in individual studies and each treatment pooled effect size were calculated using Hedge's *g*, considering an effect size of 0.0–0.2 as a trivial effect, 0.2–0.6 a small effect, 0.6–1.2 a moderate effect, 1.2–2.0 a large effect, 2.0–4.0 a very large effect, and >4.0 as an extremely large effect.[30] The precision of these estimations was represented with 95% CIs and credible intervals (CrIs).

The results of the frequentist model were summarized in a Forest plot for each outcome to show the differences between the exercise modalities and their efficacy in comparison with pharmacological treatment alone. The transitivity assumption, based on the combination of direct evidence between two treatments to create indirect evidence about a related comparison, was assessed through consistency, which implies a statistical manifestation of the similarities between the direct and indirect evidence for each comparison.[31] For this purpose, the within- and between-design consistency of the results was assessed with Cochrane's *Q* statistic test, with a $p < 0.05$ indicating a significant presence of heterogeneity and inconsistency, the inconsistency index (I^2), and the tau square (T^2) value.[32] A full design-by-treatment interaction random-effects model was used to observe the difference between fixed- and random-effects models,[33] showing a significant reduction in Cochrane's *Q* statistic for between-design consistency with the random-effects model.

The results of the Bayesian model were also summarized in Forest plots and compared with the frequentist's Forest plots to observe discrepancies between both models. Moreover, an effect estimate table for all possible treatment comparisons was elaborated with their respective CIs and CrIs. The model fit of the Bayesian network was evaluated with the residual deviance. If a study contributed disproportionally to the total residual deviance, this value would be significantly >1.[34] Leverage versus residual deviance plots were performed to evaluate the model fitness showing the contribution of individual studies to the fit and complexity of the model. Those studies that lie outside line 3 of average leverage would be considered to contribute to a worse model fit.[34] Consequently, these studies would be eliminated by a sensitivity analysis. A network meta-regression was also performed to identify if the difference in patients' mean ages between studies was influencing the migraine disability NMA due to the wide intervals presented in the results.

Lastly, the inconsistency within each intervention was evaluated with the net splitting (frequentist) and node splitting (Bayesian) methods, which show the effect estimates by direct and indirect evidence separately and if the difference in both estimations is significant ($p < 0.05$).

The presence of publication bias was assessed with comparison-adjusted funnel plots and Egger's regression test for funnel plot asymmetry. Visual asymmetry in the funnel plot and a $p < 0.05$ in the Egger's regression test indicates a possible publication bias.[26]

The "viscomp" package (https://cran.r-project.org/web/packages/viscomp/index.html) was employed to elaborate a rank heat plot to rate the exercise modalities based on their *p* scores. This method ranks the interventions with a value between 0 and 100. Higher scores indicate the superiority of this intervention over others.[35] The *p* scores should be interpreted cautiously and compared with the Forest plot, using the pharmacological treatment alone as the comparison group.[36]

RESULTS

A total of 28 studies were included in the present NMA.[37–64] The selection process is shown in a flow chart in Figure 1. The studies' characteristics regarding the sample, exercise interventions and comparators, outcome measures, and main results are represented in Table 1.[37–64]

Sample characteristics

A total of 1501 patients with migraine were included, of whom 1295 (86.3%) were female and 206 (13.7%) were male. Regarding migraine diagnosis, 1061 (70.7%) participants had episodic migraine, 110 (7.3%) had chronic migraine, and in 330 (22%) patients, no distinction was made. The mean age range was 23 to 51 years, and the body mass index range was 20 to 36 kg/m^2. Of the total 1501 participants, 1430 were ultimately analyzed.

Methodological quality and risk of bias

A total of eight studies reached a good value on the PEDro scale,[39,40,48,52,53,55,57,59] 14 studies were rated with a fair value,[37,38,41–43,45,46,49,50,56,58,60,62,63] and six studies obtained a poor

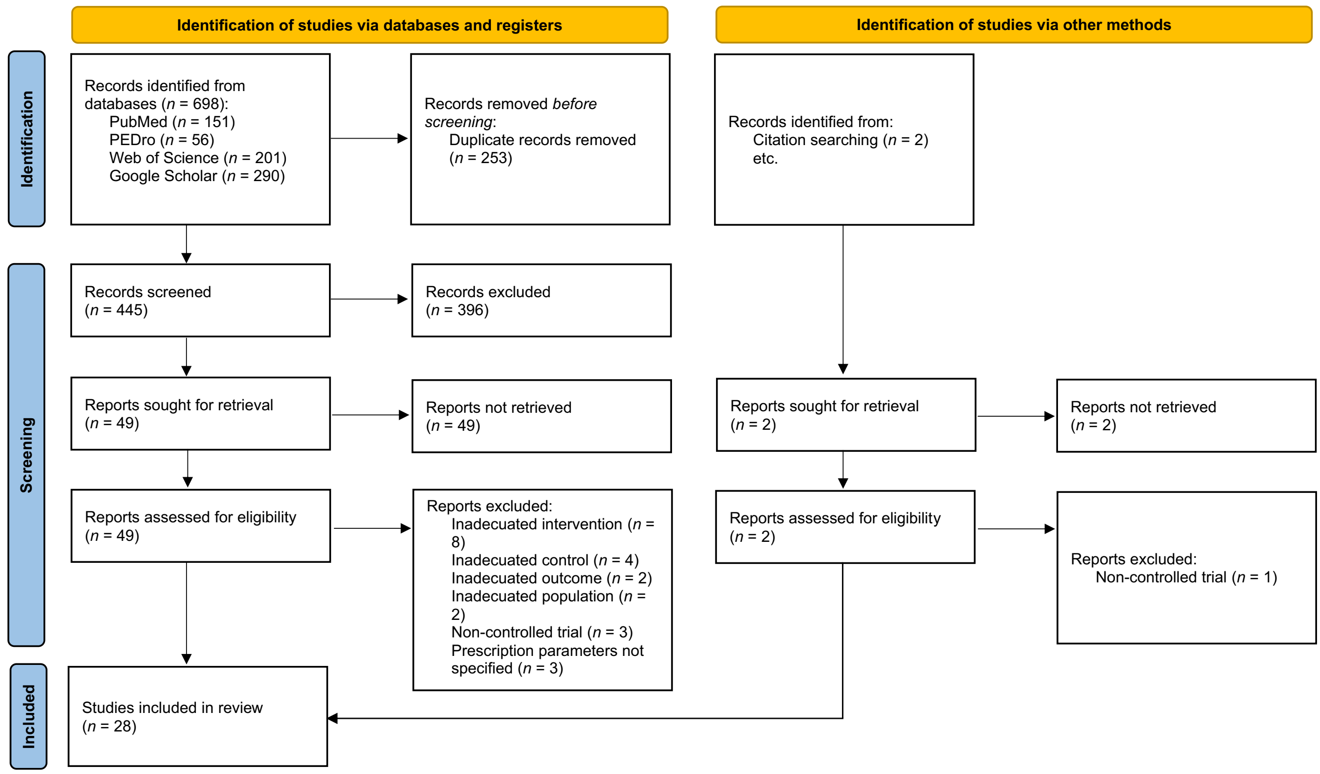

FIGURE 1 Flow chart of the inclusion and exclusion process of the studies. [Color figure can be viewed at wileyonlinelibrary.com]

value.[44,47,51,54,61,64] The concordance between reviewers was high ($\kappa=0.92$). The detailed results of the PEDro evaluation are shown in Table 2.[37–64]

Regarding the risk of bias evaluation (Figures 2 and 3), no study obtained a low risk of bias; only four studies achieved some concerns[40,53,56,59]; and 24 studies were rated with a high risk of bias.[37–39,41–52,54,55,57,58,60–64] The concordance between reviewers was moderate ($\kappa=0.662$).

Migraine frequency

A total of 25 studies evaluated the efficacy of the various exercise modalities in short-term migraine frequency.[37–41,44–63] The network graph shows the direct comparison of a total of eight exercise interventions and two comparators (Figure 4A).

Yoga (Frequentist: SMD −1.30; 95% CI −2.09, −0.51; $p=0.001$; Bayesian: SMD −1.33; 95% CrI −2.21, −0.45), high-intensity aerobic exercise (Frequentist: SMD −1.30; 95% CI −2.21, −0.39; $p=0.005$; Bayesian: SMD −1.17; 95% CrI −2.20, −0.20), and moderate-intensity continuous aerobic exercise (Frequentist: SMD −1.01; 95% CI −1.63, −0.39; $p=0.001$; Bayesian: SMD −1.06; 95% CrI −1.74, −0.38) were significantly superior to pharmacological treatment alone (Figure 5). The effect sizes, along with the CIs and CrIs for the comparisons between exercise modalities, are shown in Table 3. Additionally, the ranking of exercise interventions for the improvement of migraine frequency is illustrated in Figure 6. Yoga was considered the most probable first-line intervention according to the rank position ($p=0.76$), followed by high-intensity aerobic exercise ($p=0.75$), resistance training ($p=0.7$), and moderate-intensity continuous aerobic exercise ($p=0.62$).

High heterogeneity and inconsistency were observed (Total $Q=140.48$, $p<0.001$; within-design $Q=121.75$, $p<0.001$; between-design $Q=18.72$, $p=0.005$; $T^2=0.80$; $I^2=86.2\%$), although the Q statistic significantly decreased after assuming a full design-by-treatment interaction random-effects model (between-design $Q=2.12$, $p=0.908$; T^2 within $=1.06$). Both the net and node splitting functions revealed no significant inconsistency between direct and indirect evidence for any comparisons. Moreover, the leverage versus residual deviance plot showed that all studies correctly fitted in the model, negating the need for a sensitivity analysis (Figure 7).

The comparison-adjusted funnel plot showed no risk of publication bias, as most studies were symmetrically distributed, and the Egger's regression test was not significant ($p=0.797$) (Supplementary Material S2A).

Migraine intensity

A total of 23 studies assessed migraine intensity.[37–39,41,43–52,55–60,62–64] The network graph shows the direct comparison of eight exercise interventions and two comparators (Figure 4B).

Yoga (Frequentist: SMD −1.40; 95% CI −2.41, −0.39; $p=0.007$; Bayesian: SMD −1.41; 95% CrI −2.54, −0.27), high-intensity aerobic exercise (Frequentist: SMD −1.54; 95% CI −3.03, −0.06; $p=0.041$; Bayesian: SMD −1.50; 95% CrI −3.14, 0.09), and moderate-intensity

TABLE 1 Main characteristics of the included studies.

Study and design	Design and population	Intervention modalities and duration	Outcome measures and measurement tools	Results within and between groups
Ahmadi et al., 2015[45] Parallel RCT	Episodic migraine (ICHD-2), aura (not specified) EG: Sex: 15 F/0 M Age, years: 39.07 ± 8.83 BMI: – CG: Sex: 14 F/8 M Age, years: 38.80 ± 9.36 BMI: –	EG (n = 15): Moderate-intensity continuous aerobic exercise + pharmacological treatment as usual CG (n = 14): No exercise + pharmacological treatment as usual 8-week interventions	Migraine frequency (attacks/month) Migraine intensity (NRS) Migraine duration (average min/attack)	Within: Significant improvements in all outcomes in the EG. No significant changes in any outcome in the CG Between: No significant differences in any outcome
Aslani et al., 2021[41] Parallel RCT	Episodic migraine with or without aura (ICHD) EG: Sex: 10 F/0 M Age, years: 30.25 ± 6.10 BMI, kg/m^2: 25.03 ± 4.43 CG: Sex: 18 F/0 M Age: 30.10 ± 7.00 BMI: 23.04 ± 4.15	EG (n = 10): Resistance training + pharmacological treatment as usual CG (n = 8): Pharmacological treatment as usual 8-week interventions	Migraine frequency (attacks/month) Migraine intensity (VAS) Migraine duration (days with migraine) Disability (HIT-6)	Within: All outcomes improved significantly in the EG. No significant changes in any outcome in the CG Between: Significant differences that favor EG over the CG in all outcomes
Oliveira et al., 2017[53] Parallel RCT	Episodic migraine with or without aura (ICHD-2) EG: Sex: 10 F/0 M Age, years: 34.10 ± 12.10 BMI, kg/m^2: 25.90 ± 3.80 CG: Sex: 10 F/0 M Age, years: 33.30 ± 9.00 BMI, kg/m^2: 26.20 ± 6.70	EG (n = 10): Moderate-intensity continuous aerobic exercise + pharmacological treatment as usual CG (n = 10): Pharmacological treatment as usual 12-week interventions	Migraine frequency (days/month)	Within: Significant improvement in the EG. No significant changes in the CG Between: Analysis not performed
Oliveira et al., 2019[57] Parallel RCT	Episodic migraine with or without aura (ICHD-2) EG: Sex: 11 F/2 M Age, years: 37.40 ± 13.80 BMI, kg/m^2: 27.00 ± 4.50 CG: Sex: 9 F/3 M Age, years: 34.20 ± 9.00 BMI, kg/m^2: 25.90 ± 6.00 Sex of those dropping out unknown	EC (n = 15): Moderate-intensity continuous aerobic exercise + pharmacological treatment as usual CG (n = 15): Pharmacological treatment as usual 12-week interventions	Migraine frequency (attacks/month) Migraine intensity (0–3 numerical scale)	Within: Significant improvements in migraine frequency but no significant changes in pain intensity in the EG. No significant changes in any outcome in the CG Between: No significant differences in migraine frequency and intensity

TABLE 1 (Continued)

Study and design	Design and population	Intervention modalities and duration	Outcome measures and measurement tools	Results within and between groups
Bond et al., 2018[55] Parallel RCT	Episodic and chronic migraine with or without aura (ICHD-3) EG: Sex: 54 F/0 M Age, years: 38.50 ± 7.40 BMI, kg/m^2: 35.80 ± 6.80 CG: Sex: 56 F/0 M Age, years: 40.00 ± 8.40 BMI, kg/m^2: 35.40 ± 8.60	EG (*n* = 54): Exercise and lifestyle recommendations + pharmacological treatment as usual CG (*n* = 56): Migraine education + pharmacological treatment as usual 16-week interventions	Migraine frequency (days/month) Migraine intensity (NPRS) Migraine duration (h/attack) Disability (HIT-6)	Within: Significant reductions in all outcomes in the EG and CG Between: No significant differences in any outcome
Boroujeni et al., 2015[51] Parallel RCT	Episodic migraine (IHS), aura (not specified) EG: Sex: 15 F/0 M Age, years: 35.40 ± 7.90 BMI, kg/m^2: 66.80 ± 4.47 CG: Sex: 15 F/0 M Age: 34.90 ± 8.37 BMI: 63.80 ± 6.19	EG (*n* = 15): Yoga + pharmacological treatment as usual CG (*n* = 15): Pharmacological treatment as usual 12-week interventions	Migraine frequency (headaches/month) Migraine intensity (VAS) Migraine duration (days/attack) Disability (HIT-6)	Within: Significant improvements in migraine frequency, intensity, and disability, but not duration in the EG. No significant improvements in the CG Between: Significant differences that favor EG over the CG in migraine frequency, intensity, and disability, but not duration
Butt et al., 2022[43] Parallel nRCT	Episodic and chronic migraine with or without aura (ICHD-3 Beta) EG: Sex: 12 F/2 M Age, years: 26.21 ± 6.89 BMI: – CG: Sex: 12 F/2 M Age, years: 33.20 ± 11.69 BMI: –	EG (*n* = 14): Exercise and relaxation + pharmacological treatment as usual CG (*n* = 14): Pharmacological treatment as usual 6-week interventions	Migraine intensity (NPRS) Disability (HIT-6)	Within: Significant differences in all outcomes in the EG and CG Between: Significant differences that favor EG over the CG in all outcomes
Darabaneanu et al., 2011[47] Parallel nRCT	Episodic migraine with or without aura (IHS) EG: Sex: 6 F/2 M Age, years: 37.80 ± 8.90 BMI: – CG: Sex: 7 F/1 M Age, years: 34.10 ± 16.50 BMI: –	EG (*n* = 8): Moderate-intensity continuous aerobic exercise + pharmacological treatment as usual CG (*n* = 8): No exercise + Pharmacological treatment as usual 10-weeks interventions	Migraine frequency (days/month) Migraine intensity (NPRS) Migraine duration (h/month)	Within: Significant improvements in all outcomes in the EG. No significant changes in any outcome in the CG Between: Analysis not performed

(Continues)

TABLE 1 (Continued)

Study and design	Design and population	Intervention modalities and duration	Outcome measures and measurement tools	Results within and between groups
Eslami et al., 2021[58] Parallel RCT	Migraine (neurologist) Episodic or chronic migraine (not specified) Aura (not specified) EG 1: Sex: 12 F/0 M Age, years: 25.16 ± 6.08 BMI, kg/m^2: 21.00 ± 3.10 EG 2: Sex: 13 F/0 M Age, years: 38.41 ± 6.20 BMI, kg/m^2: 26.93 ± 5.65 CG: Sex: 15 F/0 M Age, years: 32.44 ± 5.74 BMI, kg/m^2: 24.10 ± 4.42	EG 1 (n = 12): High-intensity aerobic training + pharmacological treatment as usual EG 2 (n = 13): Moderate-intensity aerobic exercise + pharmacological treatment as usual CG (n = 15): Pharmacological treatment as usual 8-week interventions	Migraine frequency (days/month) Migraine intensity (NPRS) Migraine duration (h/month)	Within: Significant improvements in all outcomes in the EG 1 and EG 2. Significant improvements in migraine duration, but not in migraine frequency and intensity in the CG Between: Significant differences that favor EG 2 over EG 1 and CG, and EG1 over CG in migraine frequency. Significant differences that favor EG 2 over CG and EG 1 over CG in migraine intensity and duration
Hanssen et al., 2018[61] Parallel RCT	Episodic migraine without aura (ICHD-3 Beta) EG 1: Sex: 10 F/3 M Age, years: 36.20 ± 10.70 BMI, kg/m^2: 22.40 ± 3.00 EG 2: Sex: 9 F/2 M Age, years: 37.00 ± 8.70 BMI, kg/m^2: 23.60 ± 8.70 CG: Sex: 10 F/2 M Age, years: 37.30 ± 11.90 BMI, kg/m^2: 23.40 ± 2.80	EG 1 (n = 13): High-intensity aerobic interval training + pharmacological treatment as usual EG 2 (n = 11): Moderate-intensity continuous aerobic exercise + pharmacological treatment as usual CG (n = 12): Maintain habitual physical activity profile + pharmacological treatment as usual 12-week interventions	Migraine frequency (days/month)	Within: No significant improvements in any group Between: Significant differences that favor EG 1 over EG 2. No significant differences between EG 1 and CG, and EG 2 and CG
John et al., 2007[50] Parallel RCT	Episodic migraine without aura (IHS 2004) EG: Sex: 20 F/10 M Age, years: 34.38 ± 8.74 BMI: – CG: Sex: 27 F/6 M Age, years: 34.21 ± 9.66 BMI: –	EG (n = 32): Yoga + pharmacological treatment as usual CG (n = 33): Migraine education + pharmacological treatment as usual 12-week interventions	Migraine frequency (days/week) Migraine intensity (NRS) Migraine duration (h/attack)	Within: Significant improvements in migraine frequency, intensity, and duration in the EG. Significant increase of migraine frequency and intensity, but not duration in the CG Between: Significant differences that favor EG over CG in migraine frequency, intensity, and duration

TABLE 1 (Continued)

Study and design	Design and population	Intervention modalities and duration	Outcome measures and measurement tools	Results within and between groups
Kisan et al., 2014[60] Parallel RCT	Episodic migraine with or without aura (ICHD-2) EG: Sex: 21 F/9 M Age, years: 31.72 ± 10.77 BMI, kg/m^2: 23.64 CG: Sex: 19 F/11 M Age, years: 31.27 ± 8.63 BMI, kg/m^2: 23.80	EG (n = 30): Yoga + pharmacological treatment as usual CG (n = 30): Conventional care 6-week interventions	Migraine frequency (headaches/month) Migraine intensity (NRS) Disability (HIT-6)	Within: Significant improvements in all outcomes in both groups Between: Significant differences that favor EG over CG in all outcomes
Krøll et al., 2018[38] Parallel nRCT	Episodic and chronic migraine with or without aura (ICHD-III Beta) Coexisting TTH (ICHD-3 Beta) and neck pain EG: Sex: 23 F/3 M Age, years: 42.00 ± 10.90 BMI: – CG: Sex: 23 F/3 M Age, years: 36.00 ± 10.10 BMI: –	EG (n = 26): Moderate-intensity continuous aerobic exercise CG (n = 26): Carrying on with daily life as usual 12-week interventions	Migraine frequency (days/month) Migraine intensity (NPRS) Migraine duration (h/attack)	Within: Significant improvements in migraine frequency, intensity, and duration in the EG. No significant changes in any outcomes in the CG Between: No significant differences in any outcome
Kumar et al., 2020[56] Parallel RCT	Episodic migraine with or without aura (ICHD-3 Beta) EG: Sex: 58 F/22 M Age, years: 30.50 ± 8.01 BMI, kg/m^2: 24.10 ± 4.05 CG: Sex: 53 F/27 M Age, years: 31.90 ± 8.17 BMI, kg/m^2: 23.10 ± 3.85	EG (n = 80): Yoga + pharmacological treatment as usual CG (n = 80): Pharmacological treatment as usual 12-week interventions	Migraine frequency (days/month) Migraine intensity (NRS) Disability (HIT-6)	Within: Significant improvements in all outcomes in both groups Between: Significant differences that favor EG over CG in all outcomes
Kumari et al., 2022[64] Parallel RCT	Migraine with or without aura (ICHD-III) Episodic or chronic migraine (not specified) EG: Sex: 11 F/6 M Age, years: 29.88 ± 6.59 BMI: – CG: Sex: 13 F/4 M Age, years: 32.35 ± 10.19 BMI: –	EG (n = 17): Yoga + pharmacological treatment as usual CG (n = 17): Pharmacological treatment as usual 12-week interventions	Migraine frequency (headaches/week) Migraine intensity (NRS) Migraine duration (h/episode) Disability (HIT-6)	Within: Significant improvements in all outcomes in both groups Between: Significant differences that favor EG over CG in migraine intensity

(Continues)

TABLE 1 (Continued)

Study and design	Design and population	Intervention modalities and duration	Outcome measures and measurement tools	Results within and between groups
Lemstra et al., 2002[48] Parallel RCT	Chronic migraine with or without aura (IHS) EG: Sex: 32 F/12 M Age, years: 35.59 ± 10.15 BMI: – CG: Sex: 21 F/15 M Age, years: 33.17 ± 13.21 BMI: –	EG (*n* = 44): Exercise + relaxation training + stress management + massage therapy + dietary lecture + pharmacological treatment as usual CG (*n* = 36): Pharmacological treatment as usual 6-week interventions	Migraine frequency (days/month) Migraine intensity (NPRS) Migraine duration (h/month) Disability (PDI)	Within: Significant improvements in all outcomes in the EG. Significant increase of migraine frequency, intensity, and duration, but not disability in the CG Between: Significant changes favor EG over the CG in all outcomes
Matin et al., 2022[44] Parallel RCT	Episodic migraine (ICHD-2) Aura (not specified) EG: Sex: 15 F/0 M Age, years: 40.00 ± 11.61 BMI, kg/m^2: 27.75 ± 3.28 CG: Sex: 15 F/0 M Age, years: 40.00 ± 6.66 BMI, kg/m^2: 27.75 ± 5.62	EG (*n* = 15): High-intensity aerobic interval training + pharmacological treatment as usual CG (*n* = 15): Pharmacological treatment as usual 8-week interventions	Migraine frequency (days/month) Migraine intensity (10–15 disabling, 5–9 moderate, 1–4 mild) Migraine duration (min/attack) Disability (MIDAS)	Within: Analysis not performed Between: Significant differences favor EG over CG in all outcomes
Mehta et al., 2021[59] Parallel RCT	Episodic migraine with or without aura (ICHD 3) EG 1: Sex: 17 F/3 M Age, years: 39.15 ± 8.24 BMI: – EG 2: Sex: 13 F/7 M Age, years: 34.30 ± 9.57 BMI: – CG: Sex: 15 F/6 M Age: 36.81 ± 10.85 BMI: –	EG 1 (*n* = 20): PMR training + stretching + isometric exercise of neck muscles + cardiorespiratory endurance training EG 2 (*n* = 20): Yoga + pharmacological treatment as usual CG (*n* = 21): Pharmacological treatment as usual 12-week interventions	Migraine frequency (headaches/month) Migraine intensity (NPRS) Disability (HIT-6)	Within: Significant improvements in all outcomes in all groups Between: Significant differences in migraine frequency that favor EG 1 over EG 2 and CG. No significant differences in the other outcomes
Meyer et al., 2016[54] Parallel RCT	Episodic migraine with or without aura (IHS) EG: Sex: 13 F/3 M Age, years: 36.40 BMI: – CG: Sex: 18 F/1 M Age, years: 33.80 BMI: –	EG (*n* = 16): PMR training + pharmacological treatment as usual CG (*n* = 19): Pharmacological treatment as usual 6-week interventions	Migraine frequency (attacks/month)	Within: Significant improvements in frequency in the EG. No significant changes in the CG Between: Significant differences in migraine frequency that favor EG over CG

TABLE 1 (Continued)

Study and design	Design and population	Intervention modalities and duration	Outcome measures and measurement tools	Results within and between groups
Minen et al., 2020[42] Parallel RCT	Episodic and chronic migraine (ICHD-3 Beta) Aura (not specified) EG: Sex: 64 F/13 M Age, years: 41.80 ± 12.00 BMI: – CG: Sex: 52 F/10 M Age, years: 41.60 ± 13.90 BMI: –	EG (*n* = 77): PMR training + pharmacological treatment as usual CG (*n* = 62): Pharmacological treatment as usual 6-week interventions	Disability (MIDAS)	Within: No significant differences in migraine disability in any group Between: No significant differences in migraine disability
Mohammadi et al., 2020[63] Parallel RCT	Migraine (neurologist) Episodic or chronic migraine (not specified) Aura (not specified) EG: Sex: 15 F/0 M Age, years: 31.60 ± 1.50 BMI: 27.60 ± 1.50 CG: Sex: 15 F/0 M Age, years: 32.30 ± 1.10 BMI: 27.30 ± 1.50	EG (*n* = 15): Yoga + pharmacological treatment as usual CG (*n* = 15): Pharmacological treatment as usual 8-week interventions	Migraine frequency (days/month) Migraine intensity (NRS) Migraine duration (h/day) Disability (HIT-6)	Within: Significant improvements in all outcomes in the EG. No significant changes in the CG, except for disability Between: Significant differences in all outcomes that favor EG over CG
Narin et al., 2003[49] Parallel nRCT	Episodic migraine without aura (IHS) EG: Sex: 20 F/0 M Age, years: 35.20 ± 10.23 BMI: – CG: Sex: 20 F/0 M Age, years: 40.00 ± 8.30 BMI: –	EG (*n* = 20): Moderate aerobic training + pharmacological treatment as usual CG (*n* = 20): Pharmacological treatment as usual 8-week interventions	Migraine frequency (attacks/month) Migraine intensity (VAS) Migraine duration (h) Disability (PDI)	Within: Significant improvements in both groups in all outcomes Between: Significant differences in all outcomes that favor EG over CG
Pairo et al., 2016[46] Parallel nRCT	Migraine (neurologist) Episodic or chronic migraine (not specified) Aura (not specified) EG: Sex: 10 F/0 M Age, years: 38.30 ± 5.70 BMI, kg/m^2: 38.34 ± 4.94 CG: Sex: 9 F/0 M Age, years: 32.40 ± 5.70 BMI, kg/m^2: 37.18 ± 4.50	EG (*n* = 10): Moderate-intensity aerobic exercise + pharmacological treatment as usual CG (*n* = 9): Pharmacological treatment as usual 8-week interventions	Migraine frequency (days/month) Migraine intensity (NRS) Migraine duration (h/month) Disability (HIT-6)	Within: Significant improvements in all outcomes in the EG. No significant changes in any outcome in the CG Between: Significant differences in all outcomes that favor EG over CG

(Continues)

TABLE 1 (Continued)

Study and design	Design and population	Intervention modalities and duration	Outcome measures and measurement tools	Results within and between groups
Peiro et al., 2017[62] Parallel RCT	Migraine (neurologist) Episodic or chronic migraine (not specified) Aura (not specified) EG: Sex: 9 F/0 M Age, years: 22.80 ± 2.50 BMI, kg/m^2: 20.40 ± 2.80 CG: Sex: 9 F/0 M Age, years: 32.40 ± 7.50 BMI, kg/m^2: 24.10 ± 4.42	EG (n = 9): High-intensity aerobic interval training + pharmacological treatment as usual CG (n = 9): Pharmacological treatment as usual 8-week interventions	Migraine frequency (days/month) Migraine intensity (NRS) Migraine duration (h/month) Disability (HIT-6)	Within: Significant improvements in all outcomes in the EG Between: Significant differences in all outcomes that favor EG over CG
Rahimi et al., 2023[37]	Migraine with or without aura (ICHD-3 Beta) EG: Sex: 19 F/0 M Age, years: 31.61 ± 4.87 BMI: – CG: Sex: 22 F/0 M Age, years: 30.73 ± 5.88 BMI: –	EG (n = 19): Diaphragmatic breathing + jogging + pharmacological treatment as usual CG (n = 22): Pharmacological treatment as usual 12-week interventions	Migraine frequency (headaches/month) Migraine intensity (NPRS) Migraine duration (h/attack)	Within: Significant differences in all outcomes in both groups Between: Significant differences in all outcomes that favor EG over CG
Varkey et al., 2011[52] Parallel RCT	Episodic migraine with or without aura (ICHD-2) EG1: Sex: 28 F/2 M Age, years: 41.50 ± 11.40 BMI, kg/m^2: 24.10 ± 2.30 EG2: Sex: 25 F/5 M Age, years: 47.00 ± 10.80 BMI, kg/m^2: 24.90 ± 4.10	EG 1 (n = 30): Relaxation training + pharmacological treatment as usual EG 2 (n = 30): Aerobic exercise + pharmacological treatment as usual 12-week interventions	Migraine frequency (attacks/month) Migraine intensity (VAS)	Within: Significant reductions in migraine frequency and intensity in EG 1 and EG 2 Between: No significant differences in any outcome
Wells et al., 2021[40] Parallel RCT	Episodic or chronic migraine with or without aura (ICHD-2) EG: Sex: 42 F/3 M Age, years: 44.00 ± 12.00 BMI, kg/m^2: 27.00 ± 8.00 CG: Sex: 40 F/4 M Age, years: 44.00 ± 14.00 BMI, kg/m^2: 29.00 ± 7.00	EG (n = 37): Mindfulness/yoga training + pharmacological treatment as usual CG (n = 39): Headache education + pharmacological treatment as usual 8-week interventions	Migraine frequency (days/month) Disability (HIT-6)	Within: Significant improvements in migraine frequency and disability in the EG. Significant improvements in migraine frequency, but not disability, in the CG Between: Significant differences in migraine disability that favor EG over CG. No significant differences in migraine frequency

TABLE 1 (Continued)

Study and design	Design and population	Intervention modalities and duration	Outcome measures and measurement tools	Results within and between groups
Xie et al., 2022[39] Parallel RCT	Episodic migraine with or without aura (ICHD-3 Beta) EG: Sex: 42 F/0 M Age, years: 50.90 ± 10.20 BMI, kg/m^2: 22.70 ± 3.50 CG: Sex: 40 F/0 M Age, years: 47.10 ± 11.80 BMI, kg/m^2: 23.60 ± 3.80	EG (n = 40): Tai Chi + pharmacological treatment as usual CG (n = 33): Habitual exercise + pharmacological treatment as usual 12-week interventions	Migraine frequency (attacks/month) Migraine intensity (NRS) Migraine duration (h/attack)	Within: Significant reduction in migraine frequency, intensity, but not duration in the EG. No significant differences in the CG Between: Significant differences in migraine frequency that favor EG over CG. No significant differences in migraine intensity and duration

Abbreviations: BMI, body mass index; CG, control group; EG, exercise group; F, female; HDI, Headache Disability Inventory; HIT-6, six-item Headache Impact Test; ICHD, International Classification of Headache Disorders; IHS, International Headache Society; M, male; MIDAS, Migraine Disability Assessment Scale; NRS, Numeric Rating Scale; NPRS, Numeric Pain Rating Scale; nRCT, non-randomized controlled trial; PDI, pain disability index; PMR, progressive muscle relaxation; RCT, randomized controlled trial; VAS, visual analog scale.

continuous aerobic exercise (Frequentist: SMD −1.08; 95% CI −2.06, −0.10; p = 0.031; Bayesian: SMD −1.09; 95% CrI −2.19, 0.01) were significantly superior to pharmacological treatment alone (Figure 8), although high- and moderate-intensity aerobic exercise did not achieve signification in the Bayesian model. Moreover, high-intensity aerobic exercise (Frequentist: SMD −2.99; 95% CI −5.66, −0.32; Bayesian: SMD −2.94; 95% CrI −5.94, −0.02) and yoga (Frequentist: SMD −2.84; 95% CI −4.79, −0.69; Bayesian: SMD −2.85; 95% CrI −5.24, −0.43) were also superior to migraine education (Table 3). High-intensity aerobic exercise ranked first (p = 0.76), followed by yoga (p = 0.73), relaxation exercise (p = 0.65), and moderate-intensity continuous aerobic exercise (p = 0.62) (Figure 6).

The heterogeneity and inconsistency were high (Total Q = 177.08, p < 0.001; within-design Q = 107.21, p < 0.001; between-design Q = 69.87, p < 0.001; T^2 = 1.62; I^2 = 90.9%), although the Q statistic significantly decreased after assuming a full design-by-treatment interaction random effects model (between-design Q = 5.76, p = 0.33; T^2 within = 1.21). The net and node splitting functions showed no significant inconsistency between direct and indirect evidence for any comparisons. The leverage versus residual deviance plot showed that all studies correctly fit in the model. Therefore, no sensitivity analysis was performed (Figure 9).

The comparison-adjusted funnel plot showed no risk of publication bias, with most studies being symmetrically distributed and the Egger's regression test not being significant (p = 0.424) (Supplementary Material S2B).

Migraine duration

A total of 17 studies measured the changes in migraine duration.[37–39,41,44–51,55,58,62–64] The network graph shows the direct comparison of seven exercise interventions and two comparators (Figure 4C).

High-intensity aerobic exercise (Frequentist: SMD −1.64; 95% CI −2.43, −0.85; p < 0.001; Bayesian: SMD −1.56; 95% CrI −2.59, −0.63) and moderate-intensity continuous aerobic exercise (Frequentist: SMD −0.96; 95% CI −1.50, −0.41; p < 0.001; Bayesian: SMD −1.00; 95% CrI −1.71, −0.31) were significantly superior to pharmacological treatment alone (Figure 10). The effect sizes and the CIs and CrIs for the comparisons between exercise modalities are shown in Table 3. High-intensity aerobic exercise ranked first (p = 0.94), followed by moderate-intensity continuous aerobic exercise (p = 0.71), and relaxation exercise (p = 0.71) (Figure 6).

Heterogeneity and inconsistency were moderate to high (Total Q = 35.83, p < 0.001; within-design Q = 21.74, p = 0.003; between-design Q = 14.09, p = 0.003; T^2 = 0.31; I^2 = 72%), although the Q statistic significantly decreased after assuming a full design-by-treatment interaction random effects model (between-design Q = 3.52, p = 0.319; T^2 within = 0.33). The net and node splitting functions showed no significant inconsistency between direct and indirect evidence for any comparisons. The leverage versus residual

TABLE 2 Physiotherapy Evidence Database (PEDro) scale evaluation of the various studies included.

Reference	PEDro scale									
	2	3	4	5	6	7	8	9	10	11	Total
Ahmadi et al., 2015[45]	1	0	1	0	0	0	0	0	1	1	4
Aslani et al., 2021[41]	1	0	1	0	0	0	1	0	1	1	5
Bond et al., 2018[55]	1	1	1	0	0	0	0	1	1	1	6
Boroujeni et al., 2015[51]	1	0	0	0	0	0	0	0	1	1	3
Butt et al., 2022[43]	0	0	1	0	0	0	1	1	1	1	5
Darabaneanu et al., 2011[47]	0	0	1	0	0	0	0	0	1	1	3
Eslami et al., 2021[58]	1	0	0	0	0	0	1	0	1	1	4
Hanssen et al., 2018[61]	1	0	0	0	0	0	0	0	1	1	3
John et al., 2007[50]	1	0	1	0	0	0	1	0	1	1	5
Kisan et al., 2014[60]	1	1	0	0	0	0	0	0	1	1	4
Krøll et al., 2018[38]	1	1	1	0	0	0	0	0	1	1	5
Kumar et al., 2020[56]	1	1	0	0	0	0	0	1	1	1	5
Kumari et al., 2022[64]	1	0	0	0	0	0	0	0	1	1	3
Lemstra et al., 2002[48]	1	1	1	0	0	0	1	1	1	1	7
Matin et al., 2022[44]	1	0	0	0	0	0	0	0	1	1	3
Mehta et al., 2021[59]	1	1	0	0	0	0	1	1	1	1	6
Meyer et al., 2016[54]	0	0	1	0	0	0	0	0	1	1	3
Minen et al., 2020[42]	1	0	1	0	0	0	0	0	1	1	4
Mohammadi et al., 2020[63]	1	0	1	0	0	0	1	1	1	0	5
Narin et al., 2003[49]	0	0	1	0	0	0	1	1	1	1	5
Oliveira et al., 2017[53]	1	0	1	0	0	0	1	1	1	1	6
Oliveira et al., 2019[57]	1	0	1	0	0	0	1	1	1	1	6
Pairo et al., 2016[46]	1	0	1	0	0	0	1	0	1	1	5
Peiro et al., 2017[62]	1	0	1	0	0	0	1	0	1	0	4
Rahimi et al., 2023[37]	1	1	1	0	0	0	0	0	1	1	5
Varkey et al., 2011[52]	1	1	1	0	0	0	0	1	1	1	6
Wells et al., 2021[40]	1	1	1	0	0	0	0	1	1	1	6
Xie et al., 2022[39]	1	1	1	0	0	0	0	1	1	1	6

deviance plot showed that all studies correctly fitted in the model, so no sensitivity analysis was performed (Figure 11).

The comparison-adjusted funnel plot showed no risk of publication bias, with most studies being symmetrically distributed and the Egger's regression test not being significant ($p=0.51$) (Supplementary Material S2C).

Migraine disability

In all, 14 studies evaluated migraine disability changes.[40–44,46,48,49,51,55,56,59,60,64] The network graph shows the direct comparison of seven exercise interventions and two comparators (Figure 4D).

Moderate-intensity continuous aerobic exercise was the only intervention superior to pharmacological treatment alone based on the frequentist results, but not on the Bayesian model (Frequentist: SMD −4.37; 95% CI −8.14, −0.6, $p=0.023$; Bayesian: SMD −4.37; 95% CrI −9.32, 0.54) (Figure 12). The effect sizes and the CIs and CrIs for the comparisons between the exercise modalities are shown in Table 3. Moderate-intensity continuous aerobic exercise ranked first in the rank heat plot ($p=0.87$) (Figure 6).

High heterogeneity and inconsistency were observed (Total $Q=128.65$, $p<0.001$; within-design $Q=96.47$, $p<0.001$; between-design $Q=32.18$, $p<0.001$; $T^2=6.81$; $I^2=94.6\%$), although the Q statistic significantly decreased after assuming a full design-by-treatment interaction random effects model (between-design $Q=2.16$, $p=0.54$; T^2 within$=3.36$). The net and node splitting functions showed no significant inconsistency between direct and indirect evidence for any comparisons. The leverage versus residual deviance plot showed that all studies correctly fitted in the model, so no sensitivity analysis was performed (Figure 13). The meta-regression employed to assess the influence of age differences between studies did not show any

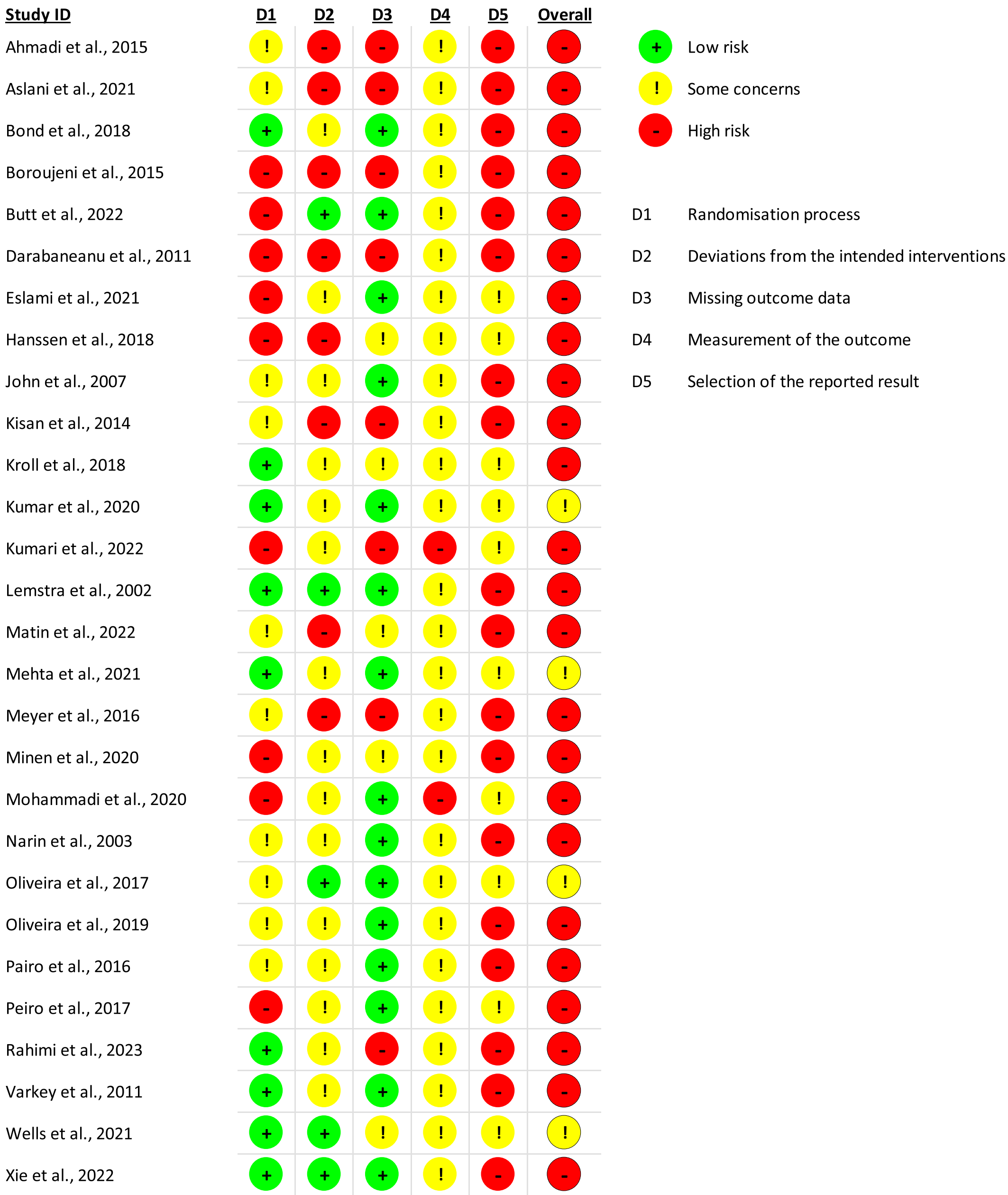

FIGURE 2 Risk of Bias 2.0 evaluation of each individual study. [Color figure can be viewed at wileyonlinelibrary.com]

significant association between age and the effect size for any intervention (B=2.75; 95% CrI −5.21, 11.08).

The comparison-adjusted funnel plot showed no risk of publication bias, with most studies being symmetrically distributed and the Egger regression test not being significant (p=0.4) (Supplementary Material S2D).

Strength of evidence

The GRADE evaluation indicated very low-quality evidence for the efficacy of various exercise interventions compared with pharmacological treatment alone across all outcomes, including high-intensity aerobic exercise, yoga, and moderate-intensity continuous aerobic exercise (Supplementary Material S3). Furthermore, there is very low-quality evidence regarding the superiority of high-intensity aerobic exercise and yoga over migraine education in decreasing migraine intensity. Lastly, there is very low-quality evidence suggesting no superiority of high-intensity aerobic exercise over yoga and moderate-intensity aerobic exercise in decreasing migraine frequency, intensity, and duration.

DISCUSSION

This NMA explored the effectiveness of various exercise modalities in managing migraine compared to pharmacological treatment alone,

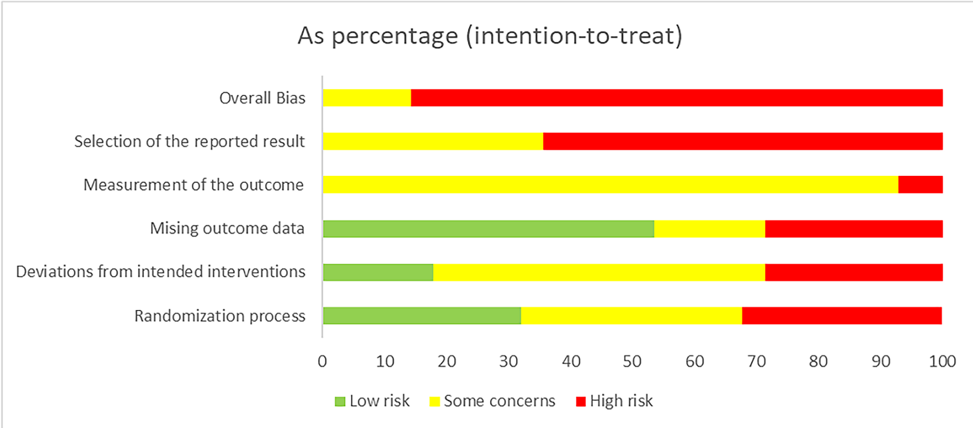

FIGURE 3 Risk of Bias 2.0 summary evaluation of each domain. [Color figure can be viewed at wileyonlinelibrary.com]

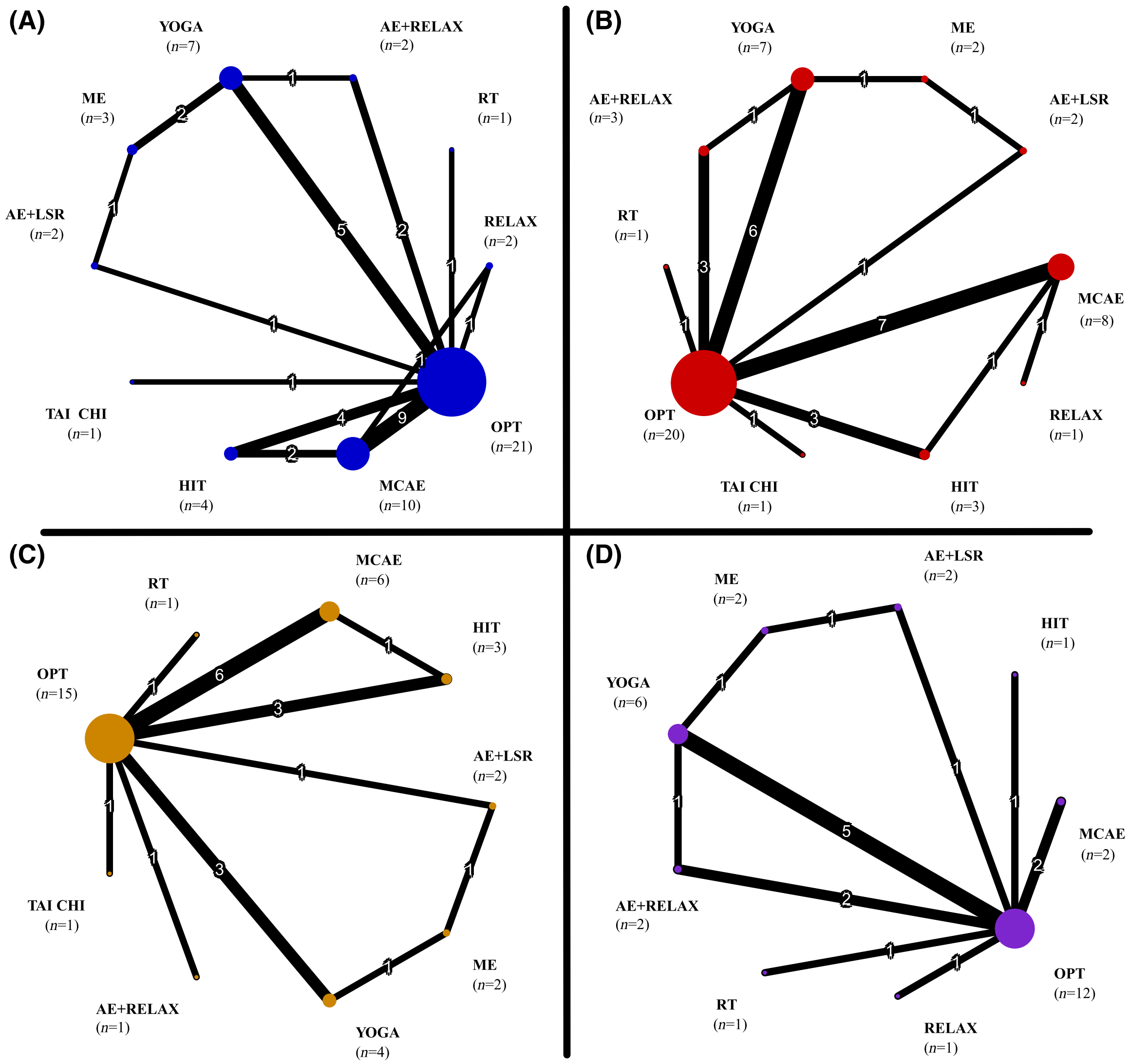

FIGURE 4 Network graphs for the various outcomes analyzed. (A) Frequency network graph; (B) intensity network graph; (C) duration network graph; (D) disability network graph. AE+LSR, aerobic exercise with lifestyle recommendations; AE+RELAX, aerobic and relaxation exercises; HIT, high-intensity aerobic training; MCAE, moderate-intensity continuous aerobic exercise; ME, migraine education; OPT, only pharmacological treatment; RELAX, relaxation exercises; RT, resistance training; TAI CHI, Tai Chi; YOGA, yoga. [Color figure can be viewed at wileyonlinelibrary.com]

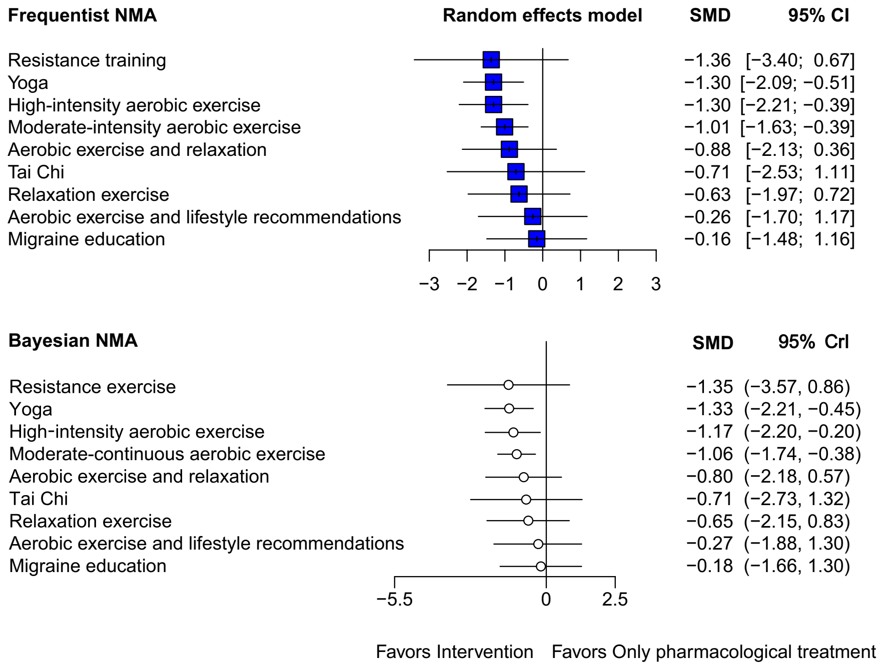

FIGURE 5 Frequentist and Bayesian forest plots of the frequency network meta-analysis. [Color figure can be viewed at wileyonlinelibrary.com]

considering various parameters: frequency, intensity, duration, and disability. Additionally, exercise modalities were compared to analyze which were superior.

The results indicated that combining pharmaceutical treatment with high-intensity exercise, yoga, or continuous moderate-intensity aerobic exercise outperforms pharmaceutical treatment alone in terms of migraine frequency and intensity; however, Bayesian results do not support the use of high- and moderate-intensity aerobic exercise interventions for decreasing migraine intensity. High- and moderate-intensity aerobic exercises were superior to pharmaceutical treatment alone regarding migraine duration. Notably, continuous moderate-intensity aerobic exercise emerged as the sole exercise modality superior to pharmaceutical treatment alone regarding migraine disability based on frequentist results, but not Bayesian results.

The exercise modalities with the most randomized controlled trials (RCTs) to date are moderate-intensity aerobic exercise and yoga. This fact has contributed to the development of systematic reviews and meta-analyses that suggest these interventions are effective in terms of migraine frequency, duration, and intensity.[11,12,65,66] This evidence, despite coinciding with some of our findings, does not correspond to a NMA. Consequently, there is no methodologically established indirect comparison between various exercise-related interventions. Our research provides a comprehensive framework in which conclusions can be drawn about the magnitude of the effect of various exercise modalities and their indirect comparison.

Similar to our methodology, Woldeamanuel and Oliveira[18] recently published a NMA on exercise and migraine. Unlike our study, they only made direct and indirect comparisons between moderate-intensity aerobic exercise, high-intensity aerobic exercise, and resistance training, focusing solely on headache frequency. In contrast, our research included eight exercise modalities and four variables. Moreover, our findings also differ in relation to headache frequency; we did not find resistance training to be an effective modality. In our study, yoga, and high- and moderate-intensity aerobic exercise demonstrated greater efficacy, aligning with the mentioned study.[18] There is emerging evidence about resistance training, supported by only two published studies. One of these studies focused on resistance training in the cervical region, showing no effect.[67] The other applied general resistance training (targeting various body areas) that was effective regarding headache intensity and frequency.[41] The findings of the clinical practice guidelines previously mentioned indicate that moderate-intensity aerobic exercise, yoga, and lifestyle recommendations that include exercise present a Grade B recommendation. On the other hand, high-intensity training, low-intensity training, relaxation exercises, resistance training, and Tai Chi obtained a Grade C.[17]

Regarding migraine intensity, high-intensity aerobic exercise, yoga, and continuous moderate-intensity aerobic exercise were the only exercise modalities significantly superior to pharmaceutical treatment alone, according to frequentist results; however, only yoga showed significant efficacy compared to pharmaceutical treatment alone in both frequentist and Bayesian models. High-intensity aerobic exercise presented the greatest effect size for this variable. Previous low–moderate quality evidence had concluded that high-intensity interval training has positive effects on reducing pain intensity in various musculoskeletal disorders.[68] Still, this type of modality is very demanding and might not be adaptable to many patients with migraine. Addressing this concern, a recent Delphi study concluded that exercise prescriptions for patients with migraine must be adapted considering patient preferences and psychological considerations, level of physical activity, and potential adverse effects.[69]

TABLE 3 Effect estimate table for all possible treatment comparisons. [Color table can be viewed at wileyonlinelibrary.com]

Frequency

AE+LSR			0.19 (−1.61; 1.98) 0.19 (−1.9; 2.3)		−0.56 (−2.37; 1.25) −0.55 (−2.6; 1.5)				
0.62 (−1.24; 2.48) 0.53 (−1.53; 2.58)	AE+RELAX				−0.75 (−2.07; 0.58)				0.37 (−1.50; 2.23) 0.67 (−1.4; 2.7)
1.04 (−0.67; 2.74) 0.90 (−0.96; 2.81)	0.42 (−1.12; 1.96) 0.37 (−1.31; 2.08)	HIT		−0.05 (−1.38; 1.27) 0.34 (−1.0; 1.7)	−1.32 (−2.29; −0.35)				
−0.11 (−1.54; 1.33) −0.10 (−1.69; 1.49)	−0.72 (−2.46; 1.01) −0.63 (−2.56; 1.28)	−1.14 (−2.74; 0.46) −1.00 (−2.79; 0.74)	ME						1.30 (−0.01; 2.60) 1.29 (−0.18; 2.8)
0.74 (−0.82; 2.31) 0.78 (−0.96; 2.51)	0.13 (−1.26; 1.52) 0.25 (−1.28; 1.79)	−0.29 (−1.28; 0.70) −0.12 (−1.23; 0.94)	0.85 (−0.61; 2.31) 0.88 (−0.74; 2.49)	MCAE	−1.02 (−1.67; −0.38) −1.04 (−1.8; −0.28)	−0.04 (−1.87; 1.78) −0.03 (−2.1; 2.0)			
−0.26 (−1.70; 1.17) −0.27 (−1.88; 1.30)	−0.88 (−2.13; 0.36) −0.80 (−2.18; 0.57)	−1.30 (−2.21; −0.39) −1.18 (−2.20; −0.20)	−0.16 (−1.48; 1.16) −0.18 (−1.66; 1.30)	−1.01 (−1.63; −0.39) −1.06 (−1.74; −0.37)	OPT	0.27 (−1.61; 2.14) 0.27 (−1.9; 2.4)	1.36 (−0.67; 3.40)	0.71 (−1.11; 2.53)	1.21 (0.38; 2.05) 1.21 (0.23; 2.2)
0.36 (−1.61; 2.33) 0.37 (−1.80; 2.56)	−0.26 (−2.09; 1.58) −0.15 (−2.17; 1.89)	−0.67 (−2.26; 0.91) −0.53 (−2.30; 1.22)	0.47 (−1.42; 2.35) 0.48 (−1.63; 2.58)	−0.38 (−1.72; 0.96) −0.40 (−1.90; 1.09)	0.63 (−0.72; 1.97) 0.65 (−0.83; 2.15)	RELAX			
1.10 (−1.39; 3.59) 1.08 (−1.66; 3.78)	0.48 (−1.91; 2.86) 0.55 (−2.07; 3.14)	0.06 (−2.17; 2.29) 0.18 (−2.28; 2.59)	1.20 (−1.22; 3.63) 1.18 (−1.49; 3.82)	0.35 (−1.77; 2.48) 0.29 (−2.02; 2.60)	1.36 (−0.67; 3.40) 1.35 (−0.86; 3.57)	0.73 (−1.71; 3.18) 0.70 (−1.97; 3.35)	RT		
0.44 (−1.87; 2.76) 0.44 (−2.14; 2.97)	−0.17 (−2.38; 2.03) −0.09 (−2.54; 2.33)	−0.59 (−2.62; 1.44) −0.47 (−2.76; 1.75)	0.55 (−1.70; 2.80) 0.53 (−1.96; 3.02)	−0.30 (−2.22; 1.62) −0.34 (−2.48; 1.77)	0.71 (−1.11; 2.53) 0.71 (−1.32; 2.73)	0.08 (−2.18; 2.34) 0.06 (−2.46; 2.55)	−0.65 (−3.38; 2.08) −0.64 (−3.68; 2.33)	TAI CHI	
1.04 (−0.44; 2.52) 1.05 (−0.57; 2.70)	0.42 (−0.93; 1.77) 0.53 (−0.95; 2.01)	0.00 (−1.20; 1.21) 0.15 (−1.18; 1.46)	1.14 (−0.03; 2.32) 1.15 (−0.15; 2.47)	0.29 (−0.71; 1.30) 0.27 (−0.84; 1.37)	1.30 (0.51; 2.09) 1.33 (0.45; 2.21)	0.67 (−0.89; 2.24) 0.68 (−1.06; 2.40)	−0.06 (−2.24; 2.12) −0.03 (−2.38; 2.37)	0.59 (−1.39; 2.58) 0.62 (−1.56; 2.83)	YOGA

Intensity

AE+LSR			0.05 (−2.47; 2.57) −0.052 (−2.9; 2.7)		−0.49 (−3.02; 2.05) −0.49 (−3.3; 2.3)				
1.91 (−0.62; 4.43) 1.91 (−0.92; 4.76)	AE+RELAX				−1.23 (−2.73; 0.27)				−0.14 (−2.71; 2.43) −0.075 (−3.0; 2.9)
2.05 (−0.53; 4.63) 2.01 (−0.84; 4.60)	0.14 (−1.92; 2.21) 0.10 (−2.13; 2.41)	HIT		0.26 (−2.36; 2.87) 0.36 (−2.6; 3.3)	−1.58 (−3.14; −0.03)				
−0.94 (−3.04; 1.17) −0.93 (−3.28; 1.43)	−2.84 (−5.44; −0.25) −2.84 (−5.76; 0.06)	−2.99 (−5.66; −0.32) −2.94 (−5.94; −0.02)	ME						3.92 (1.29; 6.55) 3.9 (1.0; 6.8)
1.58 (−0.74; 3.91) 1.61 (−1.02; 4.23)	−0.32 (−2.06; 1.42) −0.30 (−2.25; 1.62)	−0.47 (−2.13; 1.19) −0.40 (−2.25; 1.39)	2.52 (0.09; 4.95) 2.53 (−0.16; 5.26)	MCAE	−0.99 (−1.99; 0.00)	−0.10 (−2.65; 2.44)			
0.51 (−1.60; 2.61) 0.51 (−1.88; 2.89)	−1.40 (−2.84; 0.04) −1.40 (−3.01; 0.20)	−1.54 (−3.03; −0.06) −1.50 (−3.14; 0.09)	1.44 (−0.77; 3.66) 1.44 (−1.04; 3.90)	−1.08 (−2.05; −0.10) −1.09 (−2.19; 0.0004)	OPT		0.98 (−1.70; 3.67)	0.31 (−2.23; 2.84)	1.17 (0.11; 2.22) 1.2 (−0.014; 2.4;)
1.48 (−1.97; 4.93) 1.49 (−2.35; 5.42)	−0.43 (−3.51; 2.66) −0.42 (−3.86; 3.09)	−0.57 (−3.61; 2.47) −0.53 (−3.92; 2.85)	2.42 (−1.10; 5.93) 2.42 (−1.53; 6.43)	−0.10 (−2.65; 2.44) −0.11 (−2.97; 2.77)	0.97 (−1.76; 3.70) 0.98 (−2.08; 4.10)	RELAX			
1.49 (−1.92; 4.90) 1.50 (−2.30; 5.29)	−0.41 (−3.46; 2.63) −0.41 (−3.76; 2.95)	−0.56 (−3.62; 2.51) −0.52 (−3.90; 2.83)	2.43 (−1.05; 5.91) 2.43 (−1.45; 6.36)	−0.09 (−2.95; 2.77) −0.10 (−3.25; 3.07)	0.98 (−1.70; 3.67) 0.99 (−1.96; 3.96)	0.01 (−3.81; 3.84) 0.01 (−4.32; 4.26)	RT		
0.81 (−2.49; 4.11) 0.84 (−2.86; 4.51)	−1.09 (−4.01; 1.83) −1.08 (−4.35; 2.19)	−1.24 (−4.18; 1.70) −1.18 (−4.50; 2.09)	1.75 (−1.62; 5.12) 1.76222997190108 (−2.11; 5.50)	−0.77 (−3.49; 1.95) −0.78 (−3.88; 2.28)	0.31 (−2.23; 2.84) 0.32 (−2.54; 3.17)	−0.67 (−4.39; 3.06) −0.67 (−4.86; 3.57)	−0.68 (−4.37; 3.02) −0.68 (−4.76; 3.47)	TAI CHI	
1.91 (−0.28; 4.10) 1.91 (−0.54; 4.40)	0.00 (−1.64; 1.64) 0.01 (−1.81; 1.83)	−0.14 (−1.94; 1.65) −0.09 (−2.09; 1.87)	2.84 (0.69; 4.99) 2.85 (0.43; 5.24)	0.32 (−1.09; 1.73) 0.32 (−1.27; 1.88)	1.40 (0.39; 2.41) 1.41 (0.27; 2.55)	0.43 (−2.48; 3.34) 0.42 (−2.88; 3.69)	0.41 (−2.45; 3.28) 0.41 (−2.76; 3.61)	1.09 (−1.64; 3.83) 1.08 (−1.99; 4.16)	YOGA

TABLE 3 (Continued)

Duration

AE+LSR			0.14 (−1.01; 1.28) 0.13 (−1.6; 1.8)		−0.31 (−1.48; 0.86) −0.31 (−2.0; 1.4)			
1.00 (−0.60; 2.61) 1.01 (−1.14; 3.16)	AE+RELAX				−1.04 (−2.31; 0.23)			
1.60 (0.34; 2.86) 1.52 (−0.01; 3.29)	0.60 (−0.90; 2.09) 0.51 (−1.39; 2.51)	HIT		0.18 (−1.16; 1.52) 0.20 (−1.3; 1.7)	−1.83 (−2.67; −0.99)			
−0.13 (−1.10; 0.85) −0.13 (−1.5; 1.22)	−1.13 (−2.79; 0.53) −1.14 (−3.38; 1.07)	−1.73 (−3.06; −0.40) −1.65 (−3.49; 0.06)	ME					0.95 (−0.25; 2.15) 0.95 (−0.79; 2.7)
0.92 (−0.20; 2.04) 0.97 (−0.58; 2.52)	−0.08 (−1.46; 1.29) −0.04 (−1.85; 1.77)	−0.68 (−1.57; 0.20) −0.55 (−1.69; 0.47)	1.05 (−0.15; 2.25) 1.09 (−0.51; 2.74)	MCAE	−0.89 (−1.44; −0.34)			
−0.04 (−1.02; 0.95) −0.04 (−1.39; 1.34)	−1.04 (−2.31; 0.23) −1.04 (−2.72; 0.64)	−1.64 (−2.43; −0.84) −1.56 (−2.59; −0.63)	0.09 (−0.98; 1.16) 0.09 (−1.36; 1.58)	−0.96 (−1.50; −0.41) −1.00 (−1.71; −0.31)	OPT	0.40 (−1.04; 1.83)	0.58 (−0.60; 1.76)	0.46 (−0.29; 1.21) 0.46 (−0.58; 1.5)
0.36 (−1.38; 2.10) 0.37 (−1.91; 2.64)	−0.64 (−2.56; 1.27) −0.63 (−3.13; 1.83)	−1.24 (−2.88; 0.40) −1.15 (−3.26; 0.85)	0.49 (−1.30; 2.27) 0.49 (−1.81; 2.82)	−0.56 (−2.09; 0.97) −0.60 (−2.55; 1.33)	0.40 (−1.04; 1.83) 0.41 (−1.42; 2.21)	RT		
0.54 (−0.99; 2.08) 0.54 (−1.57; 2.65)	−0.46 (−2.19; 1.27) −0.48 (−2.80; 1.87)	−1.06 (−2.48; 0.37) −0.98 (−2.94; 0.85)	0.67 (−0.92; 2.27) 0.67 (−1.52; 2.85)	−0.37 (−1.67; 0.92) −0.43 (−2.18; 1.33)	0.58 (−0.60; 1.76) 0.58 (−1.04; 2.18)	0.19 (−1.67; 2.04) 0.17 (−2.23; 2.63)	TAI CHI	
0.54 (−0.53; 1.60) 0.53 (−0.94; 2.00)	−0.47 (−1.92; 0.98) −0.48 (−2.39; 1.45)	−1.07 (−2.13; 0.00) −0.99 (−2.41; 0.30)	0.66 (−0.34; 1.66) 0.66 (−0.72; 2.03)	−0.38 (−1.27; 0.50) −0.43 (−1.59; 0.73)	0.57 (−0.13; 1.28) 0.57 (−0.37; 1.49)	0.18 (−1.42; 1.77) 0.16 (−1.88; 2.20)	−0.01 (−1.38; 1.37) −0.01 (−1.89; 1.86)	YOGA

Disability

AE+LSR			−0.11 (−5.24; 5.01) −0.12 (−8.0; 7.6)		−0.56 (−5.69; 4.58) −0.58 (−8.4; 7.1)			
0.37 (−5.02; 5.75) 0.39 (−6.81; 7.54)	AE + RELAX				−0.60 (−4.26; 3.06)			0.22 (−4.93; 5.37) 0.22 (−8.; 8.3)
3.19 (−3.58; 9.95) 3.23 (−5.77; 12.29)	2.82 (−3.47; 9.10) 2.81 (−5.44; 11.11)	HIT			−3.90 (−9.16; 1.35)			
0.05 (−4.20; 4.30) 0.05 (−5.60; 5.79)	−0.32 (−5.77; 5.14) −0.34 (−7.45; 6.90)	−3.14 (−10.02; 3.75) −3.18 (−12.13; 6.04)	ME					0.93 (−4.21; 6.06) 0.91 (−6.8; 8.5)
3.65 (−2.03; 9.33) 3.64 (−3.85; 11.22)	3.28 (−1.82; 8.39) 3.26 (−3.45; 10.10)	0.47 (−6.00; 6.93) 0.43 (−8.05; 9.01)	3.60 (−2.23; 9.43) 3.61 (−4.17; 11.33)	MCAE	−4.37 (−8.14; −0.60)			
−0.72 (−4.97; 3.54) −0.72 (−6.43; 4.91)	−1.09 (−4.53; 2.36) −1.10 (−5.63; 3.46)	−3.90 (−9.16; 1.35) −3.93 (−10.86; 2.97)	−0.77 (−5.21; 3.68) −0.77 (−6.76; 5.02)	−4.37 (−8.14; −0.60) −4.37 (−9.32; 0.54)	OPT	0.27 (−4.86; 5.39)	−1.53 (−6.75; 3.69)	1.81 (−0.51; 4.13) 1.8 (−2.00; 5.7)
−0.45 (−7.11; 6.21) −0.46 (−9.39; 8.49)	−0.82 (−6.99; 5.36) −0.85 (−9.12; 7.41)	−3.64 (−10.98; 3.70) −3.68 (−13.40; 6.12)	−0.50 (−7.29; 6.28) −0.49 (−9.70; 8.46)	−4.10 (−10.47; 2.26) −4.11 (−12.67; 4.33)	0.27 (−4.86; 5.39) 0.25 (−6.56; 7.17)	RELAX		
−2.25 (−8.99; 4.49) −2.24 (−11.33; 6.61)	−2.62 (−8.87; 3.64) −2.65 (−10.92; 5.68)	−5.43 (−12.84; 1.98) −5.45 (−15.17; 4.46)	−2.30 (−9.16; 4.56) −2.31 (−11.56; 6.79)	−5.90 (−12.34; 0.54) −5.93 (−14.31; 2.67)	−1.53 (−6.75; 3.69) −1.55 (−8.40; 5.40)	−1.80 (−9.11; 5.52) −1.80 (−11.48; 7.85)	RT	
1.14 (−3.30; 5.59) 1.15 (−4.79; 7.10)	0.78 (−2.96; 4.51) 0.75 (−4.11; 5.73)	−2.04 (−7.75; 3.66) −2.06 (−9.535; 5.43)	1.09 (−3.16; 5.35) 1.10 (−4.61; 6.76)	−2.51 (−6.88; 1.86) −2.51 (−8.19; 3.28)	1.86 (−0.35; 4.08) 1.86 (−1.02; 4.88)	1.60 (−3.99; 7.18) 1.61 (−5.81; 9.14)	3.39 (−2.28; 9.06) 3.40 (−4.09; 10.95)	YOGA

Grey cells indicate the exercise modality for each column.

Green cells indicate the comparisons are significan (confidence and credible intervals that don't contain the 0).

Abbreviations: AE+LSR, aerobic exercise with lifestyle recommendations; AE+RELAX, aerobic and relaxation exercises; HIT, high-intensity aerobic training; MCAE, moderate-intensity continuous aerobic exercise; ME, migraine education; OPT, only pharmacological treatment; RELAX, relaxation exercises; RT, resistance training; TAI CHI, Tai Chi; YOGA, yoga.

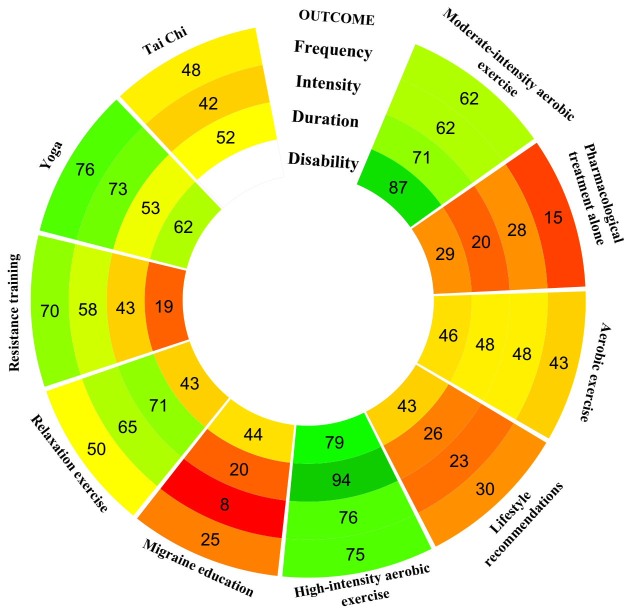

FIGURE 6 Rank heat plot of the different outcomes analyzed. Numbers and colors indicate the probability of being the first intervention recommended for a certain outcome. [Color figure can be viewed at wileyonlinelibrary.com]

Another relevant aspect is the limited number of studies related to high-intensity aerobic training. In this NMA, only four RCTs were analyzed, all exhibiting low methodological quality and high risk of bias.[44,58,61,62] High-intensity aerobic exercise and yoga were also superior to migraine education. Several systematic reviews have indicated that educational strategies for chronic pain conditions might be insufficient for achieving significant improvements when used in isolation.[70,71] Combining therapeutic education with active treatment strategies, such as exercise, may lead to more favorable outcomes.[72,73]

In terms of migraine duration, high- and moderate-intensity aerobic exercises were the only modalities superior to pharmaceutical treatment alone. High-intensity aerobic exercise was also superior to migraine education and aerobic exercise with lifestyle recommendations, as indicated by the frequentist results. It is noteworthy that lifestyle modifications, which often include dietary changes, improving sleep patterns, and stress management, along with regular exercise, have been recommended by other authors for migraine management.[74,75] Moreover, various observational studies have shown that increased levels of physical activity and the adoption of healthier lifestyle habits are associated with a reduction in migraine symptoms.[76–78]

In relation to migraine disability, the frequentist results showed that moderate-intensity aerobic exercise was the only intervention superior to pharmaceutical treatment alone. These findings are clinically significant, particularly considering that migraine disability ranges from moderate to severe.[79] It is a multidimensional, complex construct that coexists with psychological factors such as anxiety, depression,[80,81] and pain catastrophizing,[82] and some studies have found associations with obesity.[82,83]

Meta-analytical studies support the efficacy of exercise for improving body composition in individuals with obesity,[84] as well as reducing anxiety and depression.[85–87] In the case of depression, RCTs suggest that moderate-intensity aerobic exercise is the most effective intervention.[86] Regarding aerobic exercise, Irby et al.[88] mentioned that this modality is feasible and could be effective as a treatment for migraine, further proposing a model to explain the mechanisms, categorizing them into involved biological and psychological processes. The first pathway includes changes generated from the neuroinflammatory response and physiological adaptations produced by improvements in physical fitness through exercise. The second encompassed psychological factors (self-efficacy, exercise participation expectations, and outcome expectations for migraine self-management) that can influence improvements related to exercise.

Furthermore, in healthy participants, both aerobic and resistance exercises elicit exercise-induced hypoalgesia, known as the reduction in pain perception during or following a single bout of exercise.[89] Opioid and non-opioid mechanisms, such as endocannabinoid system, have been discussed as the main factors responsible for this phenomenon.[90] A protocol of exercise lasting several weeks could improve pain in the long term through these mechanisms. Aerobic exercise, specifically, has been shown to increase pressure pain thresholds and decrease pain rating in patients with musculoskeletal pain.[91] Moreover, exercise can improve sleep patterns, dietary habits, and hydration behaviors, all of which are associated with a lower migraine frequency.[77] In fact, one pilot study found that migraine frequency and disability significantly decreased when exercise was done in synchrony with the patient's chronotype, compared to out of synchrony. This finding reinforces the relevance of circadian entrainment and pain modulation.[92]

Limitations

The quality of the evidence was very low for all exercise interventions compared with pharmacological treatment alone. This underscores the need for high-quality research that can provide more robust evidence regarding the efficacy of exercise in migraine management.

Considering that four outcome measures were analyzed, a multivariate NMA would be a better approach. This method enables the establishment of a correlation between the different evaluated variables, effectively addressing missing data of those studies that did not analyze all outcomes or whose data could not be extracted.[93] It would be necessary to include a larger number of studies with more substantial sample sizes for each exercise modality to improve confidence in the multivariate NMA. Only 28 studies and eight exercise modalities were included in the present study. Migraine frequency data could be extracted from 25 studies, migraine intensity from 23, migraine duration from 17, and migraine disability from 14. It will be interesting to apply this method in the future when more studies are available for each exercise modality.

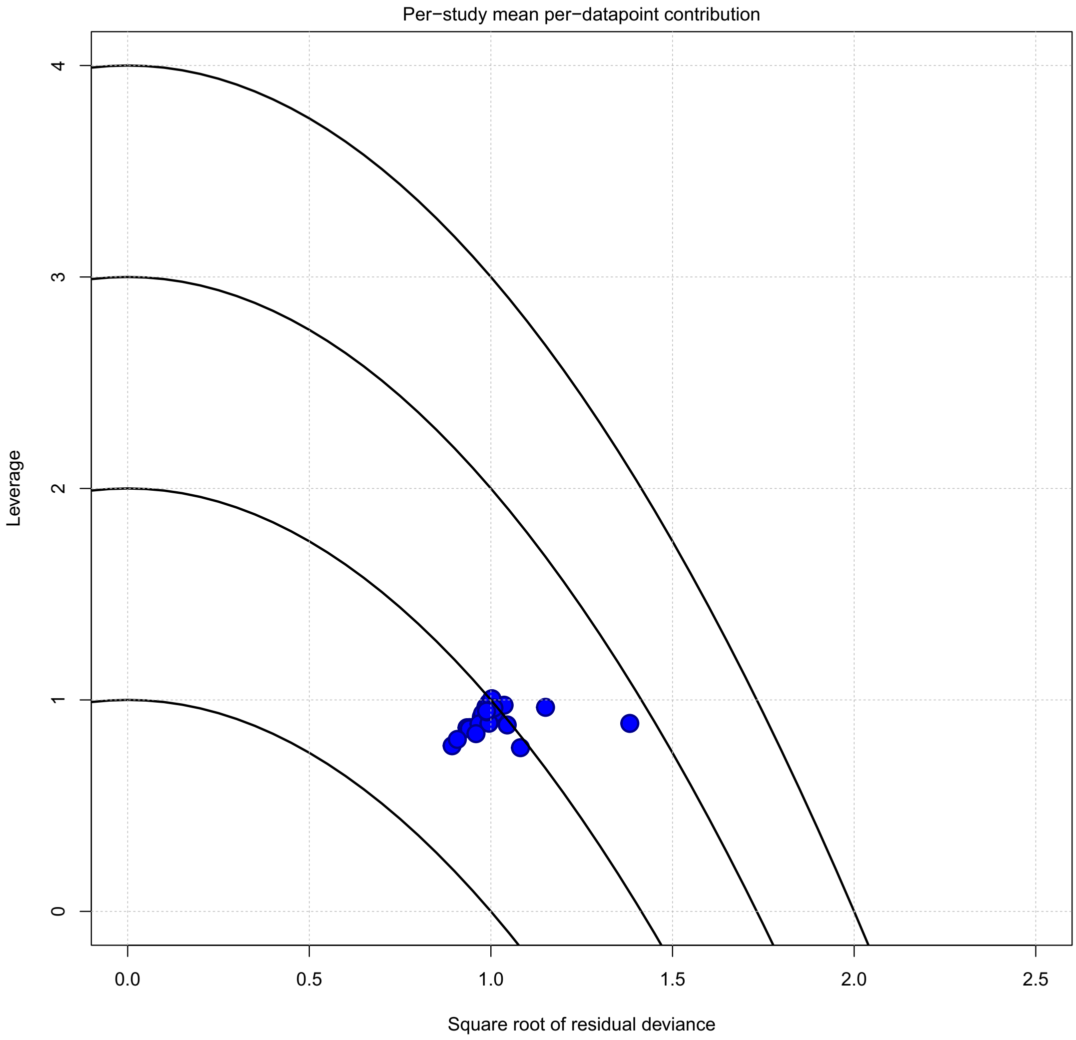

FIGURE 7 Leverage versus residual plot of the frequency network meta-analysis. [Color figure can be viewed at wileyonlinelibrary.com]

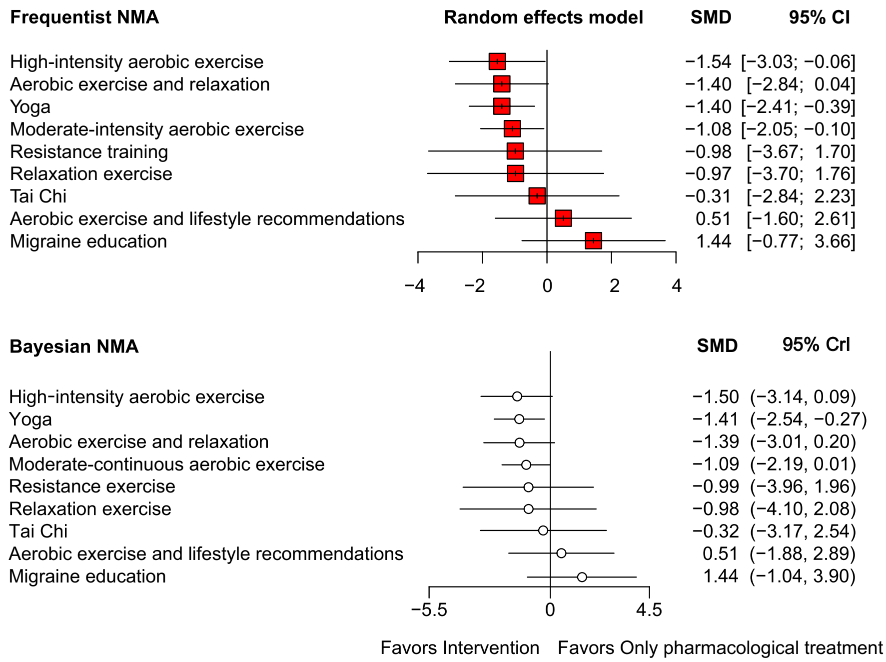

FIGURE 8 Frequentist and Bayesian forest plots of the intensity network meta-analysis. [Color figure can be viewed at wileyonlinelibrary.com]

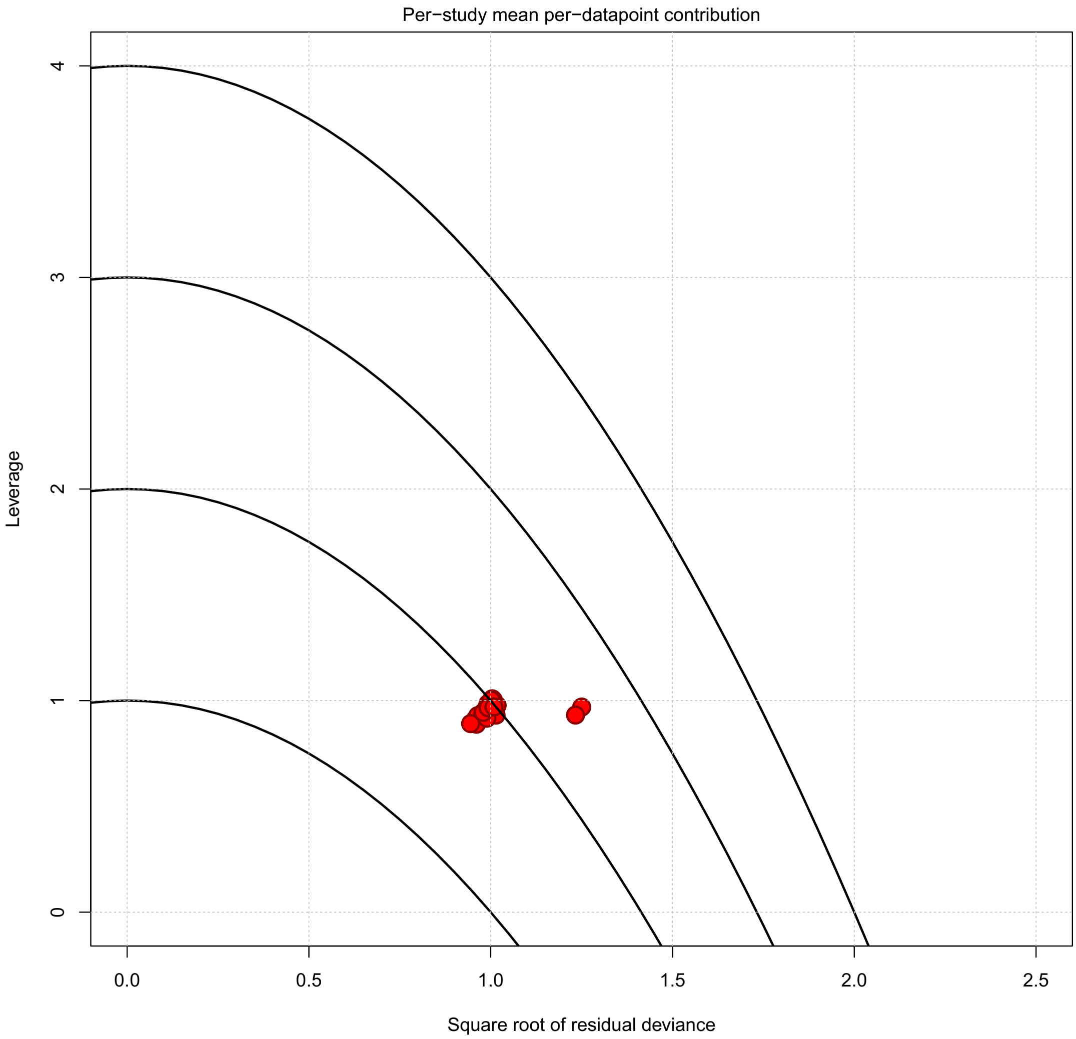

FIGURE 9 Leverage versus residual plot of the intensity network meta-analysis. [Color figure can be viewed at wileyonlinelibrary.com]

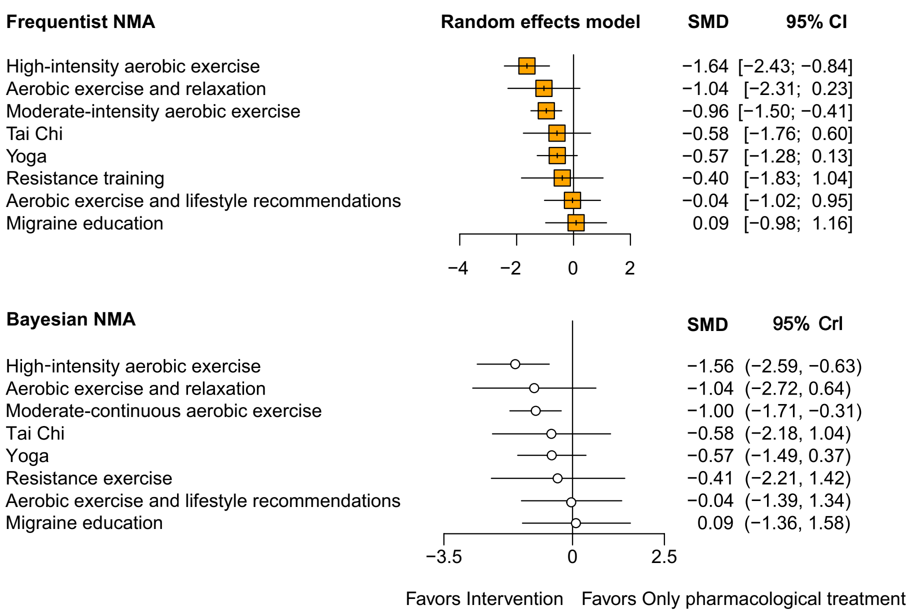

FIGURE 10 Frequentist and Bayesian forest plots of the duration network meta-analysis. [Color figure can be viewed at wileyonlinelibrary.com]

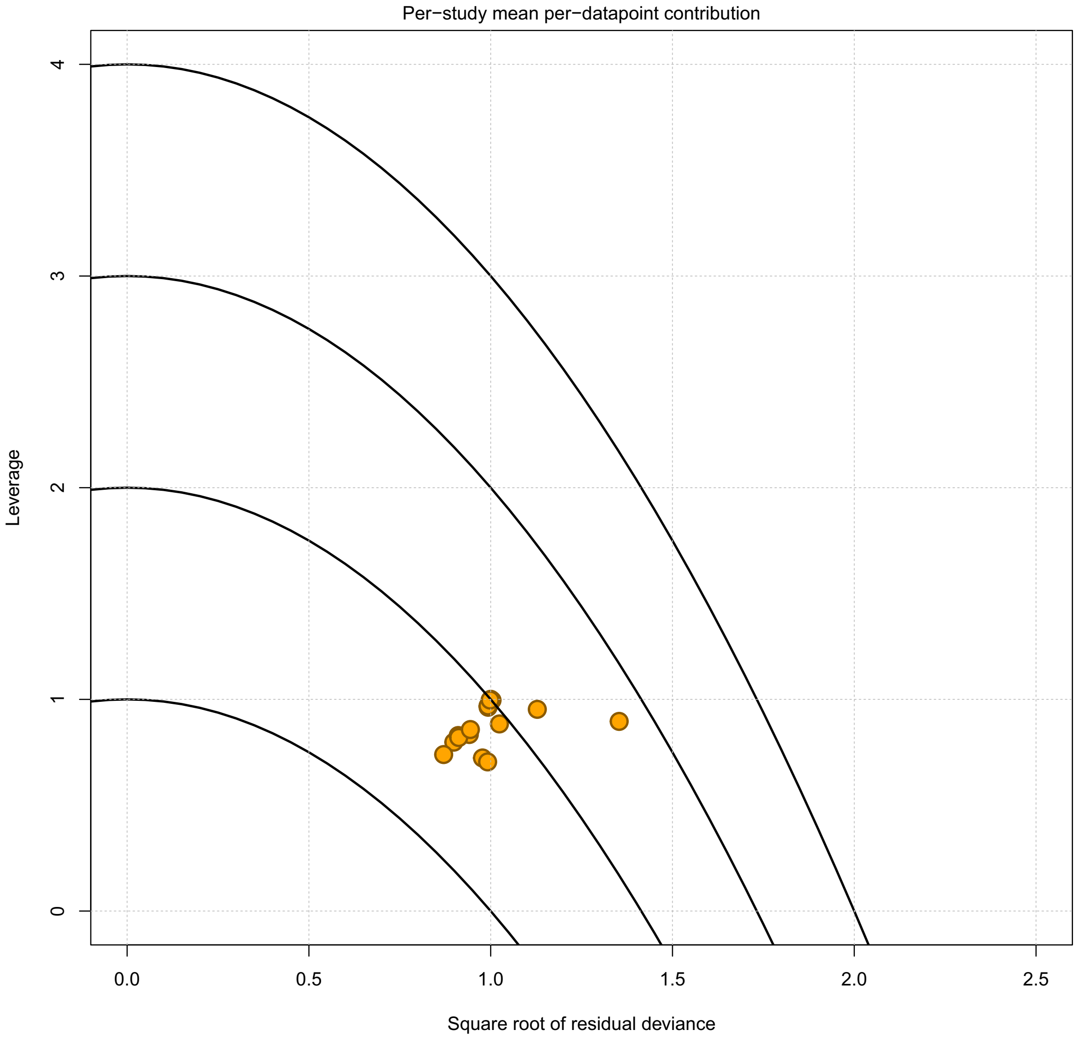

FIGURE 11 Leverage versus residual plot of the duration network meta-analysis. [Color figure can be viewed at wileyonlinelibrary.com]

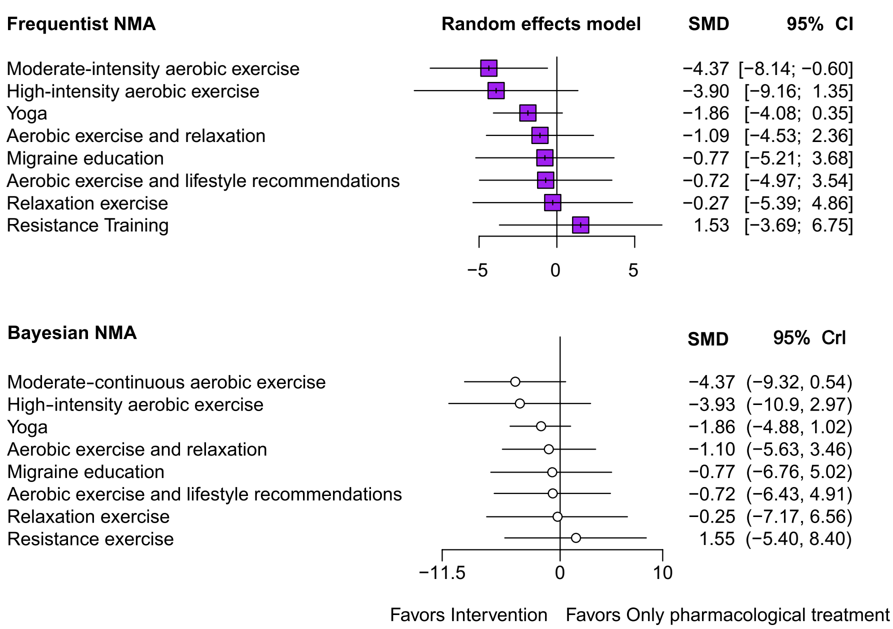

FIGURE 12 Frequentist and Bayesian Forest plots of the disability network meta-analysis. [Color figure can be viewed at wileyonlinelibrary.com]

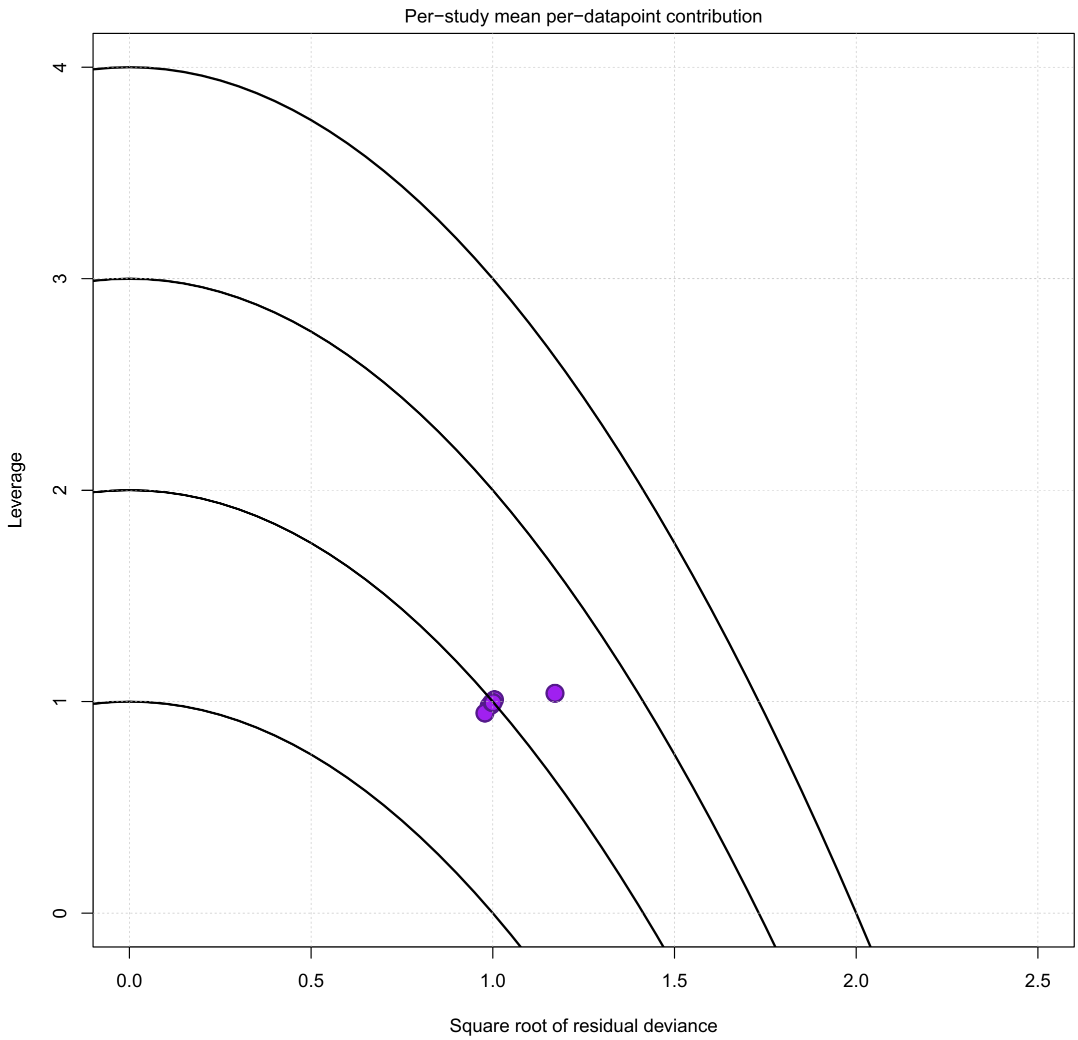

FIGURE 13 Leverage versus residual plot of the disability network meta-analysis. [Color figure can be viewed at wileyonlinelibrary.com]

The observed high level of heterogeneity and inconsistency can affect the reliability of the results. This heterogeneity might be due to the diversity of the exercise interventions and comparative treatments used in the studies, as well as to differences in outcome measures and their methodological quality. For example, while the comparator pharmacological treatment alone included common pharmacological interventions for acute and preventive management, some variations emerged among studies, with three of them excluding patients taking preventive medication.[53,54,57] Regarding exercise intervention length, although most studies applied exercise interventions of 8–12 weeks, which can be considered of similar length, the shortest exercise protocol spanned 6 weeks, while the longest extended to 16 weeks. Notably, the inconsistency significantly decreased after assuming a full design-by-treatment interaction random-effects model. Also, the fact that most studies were rated with a high risk of bias is another limitation. In some studies, we had to estimate between-group SMD and its respective variance based on the within-group SMD.[94]

Emerging evidence and expert consensus indicate that exercise can play a beneficial role in managing migraine[17,69]; however, its efficacy could depend on individual factors, including migraine characteristics, physical activity level, beliefs and attitudes towards exercise, and migraine-related emotional disturbances. In this sense, exercise interventions used in RCTs are standardized for the entire sample, highlighting an intrinsic limitation in experimental research.

Lastly, the results of the NMA are slightly influenced by the number of studies, another intrinsic limitation. High-intensity aerobic exercise yielded the largest effect sizes in two analyses, with only four studies included, compared with moderate-intensity aerobic exercise and yoga, which encompass most studies.[11,12,65,66] Conversely, aerobic exercise with lifestyle recommendations, aerobic exercise with relaxation, relaxation exercise, resistance exercise, and Tai Chi could have been underestimated due to the low number of studies and sample sizes.

Clinical implications and future research

Considering the number of studies, the moderate-to-large effect sizes, and the safety of the interventions, clinicians should consider the employment of yoga and moderate-intensity aerobic exercise in a clinical context for decreasing migraine frequency and intensity. When aiming to diminish migraine duration and disability, clinicians should consider incorporating moderate-intensity aerobic exercise, given its moderate-to-very large effect sizes. Although high-intensity aerobic exercise obtained large effect sizes and high-rank positions for decreasing migraine symptoms and disability, clinicians should be cautious in attending to the low number of studies, their high risk of bias, and the high demands intrinsic to this exercise modality. Patients with a good fitness level and response to exercise could benefit from high-intensity aerobic exercise, while those with a worse relationship with exercise could benefit from yoga and moderate-intensity aerobic exercise. Adapting the exercise modality and intensity to the patient's preference, migraine symptoms, and fitness level would also increase exercise adherence and long-term maintenance. Finally, higher-quality studies are necessary to improve the strength of the evidence regarding yoga, and high- and moderate-intensity aerobic exercise. It is also necessary to investigate other exercise interventions, such as resistance training and the combination of different exercise interventions, to broaden the spectrum of exercise options available for migraine patients.

CONCLUSION

Based on the results of both the frequentist and Bayesian NMAs, very low-quality evidence showed that yoga, high-intensity aerobic exercise, and moderate-intensity continuous aerobic exercise were effective for reducing migraine frequency; only yoga significantly decreased migraine intensity; and high- and moderate-intensity aerobic exercises significantly reduced migraine duration. The frequentist model, but not the Bayesian model, also showed that high- and moderate-intensity aerobic exercises significantly decreased migraine intensity; and moderate-intensity aerobic exercises significantly reduced migraine disability. Yoga ranked first for migraine frequency reduction; high-intensity aerobic exercise ranked first for migraine intensity and duration reduction; and moderate-intensity aerobic exercise ranked first for migraine disability reduction. The rank of high-intensity aerobic exercise should be interpreted cautiously due to the low number of studies and their high risk of bias.

AUTHOR CONTRIBUTIONS

Álvaro Reina-Varona: Conceptualization; data curation; formal analysis; investigation; methodology; software; supervision; validation; visualization; writing – original draft; writing – review and editing. **Beatriz Madroñero-Miguel:** Data curation; investigation; methodology; validation; writing – original draft. **José Fierro-Marrero:** Data curation; investigation; methodology; validation; writing – original draft. **Alba Paris-Alemany:** Conceptualization; supervision; validation; writing – original draft; writing – review and editing. **Roy La Touche:** Conceptualization; investigation; methodology; supervision; validation; writing – original draft; writing – review and editing.

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CONFLICT OF INTEREST STATEMENT

Álvaro Reina-Varona, Beatriz Madroñero-Miguel, José Fierro-Marrero, Alba Paris-Alemany, and **Roy La Touche** declare that there is no conflict of interest.

CLINICAL TRIAL REGISTRATION NUMBER

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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