

Effect of Exercise Interventions for Rheumatoid Arthritis: A Systematic Review and Network Meta-Analysis of Randomised Controlled Trials

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Objective: To compare the efficacy of various exercise modalities for Rheumatoid arthritis (RA) employing a network meta-analysis.

Methods: A systematic search was conducted across eight databases—PubMed, Embase, Cochrane Library, Web of Science, CNKI, Wanfang, VIP, and SinoMed—up to December 4, 2024, for randomized controlled trials on exercise for RA. The Cochrane Risk of Bias Assessment Tool (RoB 2) assessed study quality. A network meta-analysis was performed utilizing Stata 17.0. Our study measured outcomes through mean differences (MD) accompanied by 95% credible intervals (CIs) to quantify effect sizes, while interventions were ranked using surface under the cumulative ranking curve (SUCRA) probability scores, and the Confidence in Network Meta-Analysis (CINeMA) software to evaluate evidence certainty.

Results: A total of 34 trials included 2,435 RA patients and 10 exercise interventions: walking or jogging, relaxation training, resistance exercise, Pilates, aerobic exercise, aerobic exercise + resistance exercise, yoga, traditional Chinese exercise, cycling, and Pilates + walking or jogging. The NMA results indicated that Pilates was the most effective for pain relief (VAS: MD = -2.17 cm, 95% CI: -3.77 to -2.57, SUCRA = 91.8%); aerobic exercise + resistance exercise was most effective for reducing morning stiffness duration (MD = -8.23 min, 95% CI: -9.06 to -7.39, SUCRA = 100.0%); and traditional Chinese exercise was most effective for improving disease activity (DAS28-ESR: MD = -0.68 scores, 95% CI: -1.04 to -0.32, SUCRA = 95.5%). Risk assessment showed 4 studies “low”, 4 “high”, and 26 “some concern” regarding bias. The CINeMA assessment indicated that most comparisons provided low or very low-quality evidence.

Conclusion: Exercise interventions are effective supplements for RA treatment, with specific exercises offering distinct benefits: Pilates for pain, aerobic exercise + resistance exercise for morning stiffness, traditional Chinese exercise for disease activity. Further high-quality studies are needed for validation.

Keywords: exercise, rheumatoid arthritis, network meta-analysis, systematic review, pain, pilates

Introduction

Rheumatoid arthritis (RA) is an autoimmune joint disorder marked by joint pain, swelling, and morning stiffness.¹ RA primarily affects the small joints of the extremities, such as the hands and feet,² leading to progressive joint destruction,³ deformities, dysfunction, chronic pain, long-term disability, and premature death.⁴ Furthermore, RA patients are 32 times more likely to be unemployed due to health issues compared to the general population,⁵ exacerbating the economic burden on patients. The most recent Global Burden of Disease study reports that approximately 17.6 million people worldwide suffer from RA,⁶ with projections indicating an increase to 31.7 million by 2050, thereby placing even greater pressure on healthcare systems to meet the demand for medical resources.⁷

To date, conventional synthetic disease-modifying antirheumatic drugs (csDMARDs) continue to serve as the primary therapeutic option for RA.⁸ Although effective in controlling or delaying disease progression, their use is often limited by slow onset, adverse effects, incomplete remission, and the development of drug resistance in some patients. Moreover,

csDMARDs are typically used in combination with glucocorticoids, which amplifies the likelihood of issues like osteoporosis and infections.⁹ In recent years, the clinical use of biologics and Janus kinase (JAK) inhibitors has increased the treatment success rate in RA patients, although long-term risks of infection and tumors remain a concern.¹⁰ Therefore, exploring alternative treatments to pharmacologic therapy is crucial. Pain is one of the earliest and most debilitating symptoms in RA patients.^{5,11} Although powerful Disease-Modifying Antirheumatic Drugs (DMARDs) are effective in controlling joint inflammation, many RA patients still experience pain,^{12,13} which not only affects their quality of life but may also lead to psychological problems¹⁴ and restrictions in social interactions.¹⁵ Effective management of pain in RA patients is crucial for improving prognosis. Recent randomized controlled trials (RCTs) indicate that exercise is effective in relieving pain and fatigue, and improving physical capacity, aerobic function, psychological well-being, and sleep quality in RA patients.^{16–18} Additionally, laboratory studies have found that exercise can trigger a systemic anti-inflammatory response by promoting the secretion of myokines (such as muscle-derived Interleukin-6) from skeletal muscle and downregulating synovial inflammatory pathways.¹⁹

Exercise therapy for RA is well-established for its effectiveness, safety, affordability, and sustainability.^{20,21} During public health emergencies (eg, COVID-19 outbreaks), when access to pharmacologic treatments is limited, the importance of exercise as a complementary or alternative therapy becomes more pronounced.²² The 2022 American College of Rheumatology Guidelines for Exercise, Rehabilitation, Diet, and Additional Integrative Interventions for Rheumatoid Arthritis clearly state that regular exercise improves physical function and alleviates pain in RA patients and recommend adherence to exercise, but do not provide details on the various types of exercise.²³ RCTs on exercise for rheumatoid arthritis are growing in number,^{16–18,24,25} yet systematic evaluation studies comparing different exercise interventions remain lacking. Network meta-analysis (NMA), a statistical method based on indirect comparisons, integrates both direct and indirect evidence while simultaneously assessing the relative effectiveness of multiple interventions.²⁶ Additionally, NMA can rank the effectiveness of interventions and assist in selecting the optimal treatment regimen.^{27,28} This research pioneers NMA-based comparative efficacy rankings for diverse exercise interventions in RA management, aiming to provide evidence-based support for selecting appropriate exercise modalities to improve clinical outcomes and guide clinical practice.

Methods

The procedure for our systematic review and NMA was properly logged on PROSPERO (reference number CRD42022342845). Our study strictly followed the PRISMA guidelines of 2020 and the PRISMA-NMA extension for NMA.^{29,30} [Table S1](#) contains the PRISMA checklist.

Search Strategy

A search across eight databases—PubMed, Cochrane Library, Excerpta Medica Database, Web of Science, China National Knowledge Infrastructure, WanFang, Chinese Scientific Journal Database, and SinoMed—was conducted for RCTs on exercise for RA from the inception of each database until December 4, 2024. [Table S2](#) provides the search strategy for the corresponding databases. Three evaluators independently conducted the literature search and screening, with disagreements resolved by consulting a fourth evaluator.

Eligibility Criteria

Inclusion Criteria

- (1) Study subjects: RA patients who met the 2010 American College of Rheumatology (ACR)/ European League Against Rheumatism classification criteria or the 1987 ACR classification criteria,²⁴ with no restrictions based on age, gender, or race.
- (2) Intervention group: RA patients who received exercise therapy. Exercise was defined as a planned, structured, organized, and repetitive form of physical activity aimed at improving or maintaining one or more aspects of physical health.^{27,31,32}
- (3) Control group: RA patients receiving usual care. “Usual care” is defined as standard medical and nursing management provided in daily clinical practice, without the addition of additional structured or supervised exercise

training programs. It typically includes maintenance of usual activities, medication and follow-up as prescribed, usual care and health education (eg, advice on disease knowledge, lifestyle, and exercise benefits), psychological care, and nutritional or lifestyle counseling.

- (4) Primary outcome indicators were the visual analogue scale (VAS), morning stiffness (MS) duration, and the disease activity score 28-erythrocyte sedimentation rate (DAS28-ESR); secondary outcome measures included erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP).
- (5) Study design: RCTs.
- (6) Study language: papers were written in Chinese or English.

Exclusion Criteria

- (1) Intervention did not include exercise.
- (2) Study population consisted of non-RA patients.
- (3) Study design was non-RCT.
- (4) Animal or cellular studies were included.
- (5) Studies that were repeatedly published.
- (6) Review articles and conference papers with unavailable full text.

Study Selection

In accordance with the research protocol, two researchers independently searched and screened the literature. Discrepancies prompted consultation with a third party to validate data integrity. First, the literature retrieved from the database was imported into EndNote20 software and de-duplicated using both automatic and manual methods. Next, the titles and abstracts were reviewed for initial screening to exclude non-compliant studies. Finally, the final included studies were identified by reviewing the full text.

Data Collection

For eligible studies, we extracted information: study characteristics (first author's name and year of publication), study population (sample size, age, and gender), treatment modalities (type of treatment and specific details), and study outcomes. Data were extracted and verified by two independent reviewers. Any inconsistencies were resolved and arbitrated by a third reviewer.

Risk of Bias and Evidence Quality Assessment

The methodological quality of the included studies was assessed using the Cochrane Risk of Bias Tool (version 2), which examines potential biases across several domains: randomization procedures, adherence to intervention protocols, handling of missing data, outcome assessment methods, and selective reporting tendencies.³³ For each criterion, studies were classified as having either a low risk of bias, presenting some concerns, or demonstrating a high risk of bias. Two reviewers independently assessed the risk of bias of the included studies. Conflict resolution involved consulting an additional evaluator, and the final decision was made collectively by all three reviewers. Additionally, we used confidence in network meta-analysis (CINeMA) software to assess the evidence from the included studies, addressing six domains: internal bias, publication bias, indirect evidence, variability, inconsistency, and lack of coherence.^{34,35}

Statistical Analysis

Data were analyzed with Stata. All outcome measures were continuous variables, with results expressed as mean differences (MD). A NMA was conducted using a random-effects model. Evidence networks were constructed to illustrate the relationships between interventions, with node size representing sample size and edge thickness indicating the amount of direct evidence between interventions. Inconsistency was considered absent when $P > 0.05$ and was assessed using the consistency model. Interventions were ranked based on the surface under the cumulative ranking curve (SUCRA), with higher SUCRA values indicating superior efficacy. Comparison-adjusted funnel plots were employed to evaluate publication bias. We also performed conventional pairwise meta-analyses with Stata.

Results

Study Selection

A total of 15,037 documents were retrieved from eight databases and managed using EndNote 20. Initially, the list was trimmed by removing 2,557 duplicates. Subsequently, after an initial glance at the titles and summaries, an additional 11,313 studies were set aside. Finally, the 1,167 remaining candidates were subjected to a closer examination of their complete texts, resulting in 34 studies being included.^{16–18,24,25,36–64} Of these, 24 were in English and 10 in Chinese. Figure 1 depicts the review methodology.

Study Characteristics

34 studies were included across 10 nations, encompassing 2,435 RA patients split between the intervention (1,252) and control (1,183) groups. Eleven different therapeutic measures were used in these 34 studies, including usual care (UC), walking or jogging (WJ), relaxation training (RT), resistance exercise (RE), Pilates, aerobic exercise (AE), aerobic exercise + resistance exercise (AE + RE), yoga, traditional Chinese exercise (TCE), cycling, and Pilates + walking or jogging (Pilates + WJ). The basic characteristics of the included studies are summarized in Table 1.

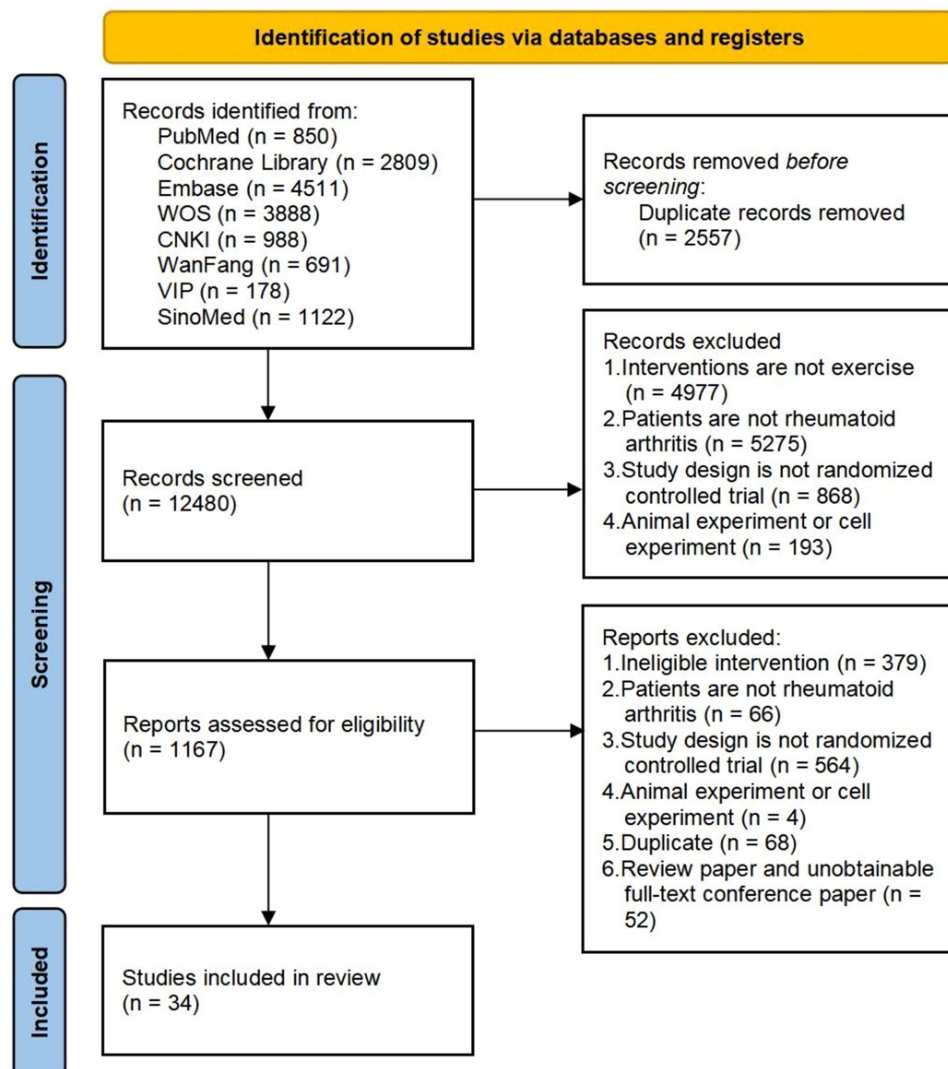


Figure 1 Flowchart of the search for eligible studies. Embase Database: Excerpta Medica Database; WOS: Web of Science Database; CNKI: China National Knowledge Infrastructure; WanFang: the WanFang Database; VIP: the Chinese Scientific Journals Full-Text Database; SinoMed: the Chinese Biomedical Literature Database.

Table 1 Characteristics of Included Studies

Study ID	Gender (Male/Female)	Average Age	Sample Size	Treatment	Detail	Length	Outcomes	
B. J. Andonian (2024) ¹⁶	NA	65.6	12	Aerobic exercise+ Resistance exercise	Do 150 minutes of moderate-to-vigorous aerobic activity weekly. Strength train twice a week with 10–11 exercises (1–3 sets of 8–15 reps) for all major muscle groups.	16 weeks	D	
	NA	67.7	12	Usual care	Attend two 60-minute lifestyle counseling sessions, then continue usual care.			
A. Kılıç (2023) ¹⁷	NA	46.3	37	Relaxation training	Patients inhale deeply while contracting their muscles and exhale as they relax, progressing. The program consists of two sessions: the first lasting 10 minutes and the second 35 minutes, performed twice daily for six weeks.	6 weeks	NA	
	8/29	56.6	37	Usual care	Health status information is collected through weekly telephone interviews.			
A. Ayyildiz (2023) ¹⁸	0/24	41.4	24	Resistance exercise	3 weekly sessions, with one conducted by a physical therapist and the remaining sessions performed by the patient at home, each lasting 50 minutes.	12 weeks	NA	
	0/23	43.7	23	Walking or jogging				Perform on a treadmill (20 minutes at 85% of maximal heart rate) or brisk walking outside the hospital.
	0/23	42.3	23	Relaxation training				Hip flexion, extension and abduction, knee flexion and extension, and ankle flexion and extension.
Tian C (2024) ²⁴	NA	54.8	33	Traditional Chinese exercise	Perform Yijinjing exercises three times a week for 12 weeks. Each session lasts 1 hour and includes three complete sets of Yijinjing exercises.	12 weeks	A C	
	NA	51.63	33	Usual care	Receive routine joint rehabilitation guidance, including energy conservation and protection, without additional exercise interventions.			
S. Gautam (2023) ²⁵	6/26	46.0	32	Yoga	The intervention consists of yogic practices, including asanas, pranayama, dhyana, and savasana, followed by interactive counseling sessions on yoga, stress management, nutrition, and personal lifestyle management. Include five weekly sessions, each lasting 120 minutes, for a duration of eight weeks.	8 weeks	C	
	9/23	41.8	32	Usual care	Continue regular medical care and maintain normal daily physical activities and lifestyle.			
Zhang BS (2024) ³⁶	NA	NA	35	Resistance exercise	Warm up for 10 minutes, then perform range-of-motion and strength training with weight-bearing resistance for 3–5 minutes. Perform resistance exercises with elastic objects and rubber bands for 3–5 minutes, repeated for 2–5 sessions, 1–2 times per day, followed by 5–10 minutes of relaxation and stretching.	6 months	NA	
	NA	NA	35	Usual care	Routine treatment, nursing care, and targeted drug therapy			
Sima PP (2024) ³⁷	26/20	50.13	46	Aerobic exercise+ Resistance exercise	Select appropriate aerobic exercises, such as brisk walking, cycling, or swimming, for 10–20 minutes per session, 2–3 times per day. Incorporate strength exercises, such as weightlifting, dumbbell training, or machine-based training, performing 8–12 repetitions for 2–3 sets per muscle group.	NA	NA	
	28/18	50.22	46	Usual care	Routine health education and functional exercise.			
Liu M (2024) ³⁸	24/35	53.86	59	Resistance exercise	Implement a chronic disease management model. Strength training is performed 2–3 times per week, with each session lasting 30–60 minutes.	3 months	A B D E	
	23/36	55.03	59	Usual care	Adopt routine nursing measures			

(Continued)

Table I (Continued).

Study ID	Gender (Male/Female)	Average Age	Sample Size	Treatment	Detail	Length	Outcomes
You DD (2023) ³⁹	39/47	48.32	86	Traditional Chinese exercise	The nursing staff guides the patients to exercise together once daily.	NA	NA
	40/46	49.65	86	Usual care	Routine nursing includes signs monitoring and care, environmental intervention, psychological nursing, rehabilitation training and continuous nursing.		
K. Loeppenthin (2022) ⁴⁰	4/13	57.8	17	Cycling	Consist of 18 cycling sessions: 3 sessions of 20 to 30 minutes per week for 6 weeks. Each session is initiated by a 5-minute warm-up, followed by four blocks of 5–7.5-minute alternating periods of continuous moderate intensity (40%–50%) and intermittent high-intensity aerobic exercise (70%–80% watt max), and finally a 5-minute cooldown.	6 weeks	A
	1/20	54.8	21	Usual care	Receive usual care and maintain normal everyday activities.		
S. Gautam (2022) ⁴¹	8/62	44.63	70	Yoga	Each session includes a set of asanas, pranayama and dhyana for approximately 120 min per day. The sessions are held five times a week for eight weeks.	8 weeks	C
	14/56	47.01	70	Usual care	Continue with their medicines and also to maintain day-to-day activities.		
Jie D (2022) ⁴²	2/8	52.4	10	Traditional Chinese exercise	Consist of tai chi session and hand exercise. The tai chi session includes 10 minutes of warm-up exercise, 20 minutes of tai chi walking, and 20 minutes of tai chi motions.	12 weeks	B D E
	2/8	52.4	10	Usual care	Maintained original life.		
Zhang SY (2022) ⁴³	24/20	67.33	44	Traditional Chinese exercise	Once daily for 30 minutes for the first 2 weeks. In the third and fourth weeks, master Baduanjin Eight-style exercises, 30 minutes each time, 3 times a day.	4 weeks	A
	22/22	67.93	44	Usual care	Routine health education management.		
Cui S (2022) ⁴⁴	10/20	45.79	30	Aerobic exercise+ Resistance exercise	Aerobic exercise, strength training, joint gymnastics, and strength training.	NA	B
	12/18	45.62	30	Usual care	Routine care.		
S.B. Yentur (2021) ⁴⁵	NA	48.2	10	Pilates	3 times in a week and 45 min per session. Including breath control, postural exercises, sitting exercises, and proprioceptive exercises. Stretching, relaxation, and postural exercises are used for cool-down.	8 weeks	A
	NA	50.7	10	Walking or jogging	Walk on treadmill for three times in a week. The aim is to reach 60–80% of maximum heart rate as training workload.		
	NA	50.7	10	Pilates+ Walking or jogging	Walking is applied to the patients, and then pilates exercises are applied after 15 min of resting period for 3 times in a week.		
Wang ZH (2021) ⁴⁶	20/17	43.26	37	Aerobic exercise+ Resistance exercise	Aerobic exercise is performed 5 times a week for 20min each time. Strength exercises are performed 5 times a week for 20min each time. Muscle strengthening exercises are performed twice daily for 5 minutes. Joint movement is performed once a day for 15 minutes.	1 month	A B
	19/18	43.7	37	Usual care	Carry out routine nursing, strictly follow the doctor's advice for medication guidance, and inform the disease and treatment related knowledge, charge the matters needing attention during rehabilitation, and guide daily life.		

(Continued)

Table I (Continued).

Study ID	Gender (Male/Female)	Average Age	Sample Size	Treatment	Detail	Length	Outcomes
A. Pukšić (2021) ⁴⁷	0/30	52.9	30	Yoga	Two times weekly with 90 min per session for 12 weeks. The session starts with a guided relaxation, which is followed by the practice of physical postures and breathing exercises, short relaxation, a special alternate nostril breathing technique, self-inquiry meditation and closing OM chant.	12 weeks	A
	3/24	57.9	27	Usual care	1 weekly sessions, 60-minute educational lectures on arthritis-related topics.		
S.G. McKenna (2021) ⁴⁸	0/10	58	10	Walking or jogging	A walking-based intervention consisting of 28 sessions, spreads over 8 weeks (2–5 times/week).	8 weeks	A
	0/10	56	10	Usual care	Receive verbal and written advice on the benefits of exercise.		
S. Gautam (2021) ⁴⁹	6/29	45.6	35	Yoga	Yogic practices include asanas, pranayama and dhyana. Five times a week 120 min duration per session for 8-weeks.	8 weeks	C
	8/27	44.5	35	Usual care	Continue with usual medical care and maintain normal daily physical activities.		
S. Rezaei (2020) ⁵⁰	NA	40.4	28	Walking or jogging	30 walks over 8 weeks (5 in weeks 1 and 2, 4 in weeks 3 and 4, and 3 in weeks 5 to 8). From week 1 to week 8, exercise duration decreased from 60 to 30 minutes and exercise intensity increased from 60% to 70%.	8 weeks	NA
	NA	41.2	28	Usual care	Only medication (routine treatment).		
S. Gautam (2020) ⁵¹	5/28	45.1	33	Yoga	Five times a week, each lasting 120 minutes, for 8 weeks. Including asanas, pranada, meditation, and savasana, followed by interactive counseling sessions on yoga, stress management, nutrition, and personal lifestyle management.	8 weeks	C
	8/25	43.4	33	Usual care	Continue with usual medical care.		
A. Ganesan (2020) ⁵²	NA	41.33	83	Yoga	Each lasting 30 minutes, 3 times a week. Yoga therapy originally consists of warm-up, sukshma vyayama, some asanas, pranayama, and zen (meditation). When fully trained, yoga therapy includes all asanas and pranayama.	12 weeks	NA
	NA	42.59	83	Usual care	Only standard medical treatment.		
Zeng YY (2020) ⁵³	16/18	37.73	34	Aerobic exercise	An average of 3 sessions per week for 8 weeks. The amount of exercise is divided into three stages according to the increasing trend.	8 weeks	NA
	15/19	36.75	34	Usual care	Health education and maintain daily living status.		
A. Gautam (2019) ⁵⁴	7/29	45.7	36	Yoga	Each session of this program lasts for 120 min per day and 5 sessions per week for 8 weeks. The session includes a set of different asanas, pranayama and dhyana suitably.	8 weeks	C D E
	9/27	42.1	36	Usual care	Maintain daily routine.		
L.Ward (2018) ⁵⁵	0/13	50	13	Yoga	Group practice consists of once-weekly 75-min yoga classes. Home practice consists of a 20-min guided relaxation, based on the relaxation technique practised in the group sessions. Perform 3 times a week according to a CD recorded by a yoga instructor.	8 weeks	A
	1/12	59	13	Usual care	Continue with usual medical care.		
F.M. Lourenzi (2017) ⁵⁶	2/25	52.63	27	Resistance exercise	Two sets of eight repetitions are performed. The first set with 50% of one repetition maximum, and the second set with 70% of one repetition maximum. A rest interval of two minutes is given between sets. Twice a week, each session lasting 50 to 60 minutes, over a 12-weeks period.	12 weeks	NA
	3/30	50.88	33	Usual care	Conventional medical treatment and contact with the investigator by telephone or Email once a week.		

(Continued)

Table 1 (Continued).

Study ID	Gender (Male/Female)	Average Age	Sample Size	Treatment	Detail	Length	Outcomes
Y.J. Shapoorabadi (2016) ⁵⁷	NA	51.18	18	Cycling	For 12 min during the first session and gradually it increases to 35 min during the 8 weeks of the study. The exercise is conducted at a submaximal intensity (60–70% of reserve heart rate).	8 weeks	NA
	NA	52.67	18	Usual care	Only medication for 8 weeks.		
S.V. Baxter (2016) ⁵⁸	NA	66.6	11	Walking or jogging	Receive instructions on a walking route with three loops, and complete 3–4 times per week, at moderate intensity (6 on a 10-point scale of self-rated exertion levels).	6 weeks	NA
	NA	59.4	22	Usual care	Receive a nutrition education session.		
Zhang C (2015) ⁵⁹	NA	NA	30	Traditional Chinese exercise	Health education, establish health records, telephone follow-up is conducted once a week, and life guidance is given, and Baduanjin practice once a day in the morning and evening, 20 minutes each time, for 3 months.	3 months	NA
	NA	NA	30	Usual care	Health education, establish health records, telephone follow-up is conducted once a week, and life guidance is given.		
G.S. Metsios (2014) ⁶⁰	NA	NA	20	Aerobic exercise+ Resistance exercise	Perform a 6-month individualised resistance and aerobic exercise training.	6 months	NA
	NA	NA	20	Usual care	Receive only advice about the benefits of exercise.		
He P (2012) ⁶¹	NA	NA	45	Traditional Chinese exercise	The basic Wuqinxi training is carried out for 1 week at first, and the experiment is carried out after proficiency. The exercise is performed once a day, each time for 3 times, a total of 40 minutes, and lasted for 6 months. The heart rate reaches (170-age) beats/min for more than 15 minutes.	6 months	B D E
	15/25	46.8	40	Usual care	Maintain a normal life.		
Wang CC (2008) ⁶²	2/8	48	10	Traditional Chinese exercise	Two 60-min Tai Chi sessions are conducted each week for 12 weeks. Each session included: 10 min of warm-up and a review of Tai Chi principles; 30 min of Tai Chi exercises; 10 min of breathing technique, and 10 min of relaxation.	12 weeks	A D E
	3/7	51	10	Relaxation training	Two 60-min sessions per week for 12 weeks. Each session starts with 40 min of information. The final 20 min consists of stretching exercises involving the upper body, trunk and lower body, each stretch being held for 10–15s.		
Yang DJ (2005) ⁶³	13/72	42	85	Aerobic exercise	Receive 30-minute active resistance training each time, four times a week, and a total of 12 weeks. While training, the heart rate reached 60% to 80%.	12 weeks	NA
	30/11	46	41	Usual care	Only the routine medicative therapy.		
A. Lundgren (1999) ⁶⁴	7/30	57	37	Relaxation training	For 30 minutes, twice a week. A supervising physical therapist is always present to correct errors or assist patients experiencing difficulties.	10 weeks	NA
	9/22	57	31	Usual care	Follow regular medical check-ups, treatments, and physiotherapy programs.		

Abbreviations: The meaning of the number represented in the Outcome, A, Visual Analogue Scale (VAS). B, morning stiffness duration. C, Disease Activity Score 28-Erythrocyte Sedimentation Rate (DAS28-ESR). D, Erythrocyte Sedimentation Rate (ESR). E, C-Reactive Protein (CRP).

Risk of Bias in Included Studies

Regarding randomization, 13 studies mentioned randomized groups but did not specify the randomization method, while 21 studies used randomized numeric tables, and 1 study did not report whether baseline characteristics were comparable between groups. Consequently, 20 studies were assessed as having a “low risk” of bias, while the others were categorized

as having “some concern.” Regarding blinding, only 8 studies were conducted using the single investigator blindness, while the remaining studies did not mention blinding. Regarding missing outcome data, nine studies explicitly stated that they reported all outcome data, while the others did not. For outcome measures, 3 studies were rated as “high risk”, 6 as “low risk”, and the remaining studies as “some concern.” Regarding selective reporting of outcomes, 17 studies had trial registration. A comparison of outcome measures in the protocol with those in published articles revealed no selective reporting. All 17 studies were judged to be “low risk”, and the rest were “some concern”. Overall, bias assessments revealed “low risk” in 4 investigations, “high risk” in 4, and “some concern” in the other 26. The findings from the risk of bias evaluation for all studies incorporated are illustrated in [Figure 2](#).

Pairwise Meta-Analysis

We performed a paired meta-analysis of all interventions for the five outcomes. Forest plots and heterogeneity analyses of pairwise meta-analyses of outcomes are provided in [Figure S1.1–1.5](#). Compared with usual care, the MD of VAS score for exercise intervention was -1.15 cm (95% CI: -1.38 to -0.93), and morning stiffness duration had a MD of -4.64 minutes (95% CI: -7.37 to -1.92), DAS28-ESR MD = -0.39 scores (95% CI: -0.57 to -0.20), ESR MD = -6.79 mm/h (95% CI: -13.54 to -0.03), CRP MD = -3.36 mg/L (95% CI: -6.31 to -0.40). Except for ESR, pairwise comparisons between exercise intervention and routine care were statistically significant.

Network Meta-Analysis

The network structure diagram for all outcome indicators is presented in [Figure 3](#). The results of the league table are presented in [Figure 4](#). We calculated the SUCRA values for different treatment modalities based on all outcome indicators ([Table S3.1–3.5](#)) and displayed them in a cumulative frequency ranking graph ([Figure S2.1–2.5](#)). The relative efficacy of each treatment modality was comprehensively evaluated based on the league table and SUCRA values.

VAS

A total of 10 research^{38,40,43,45–48,55,62} reported VAS covering 10 therapeutic modalities: relaxation training (1), yoga (2), UC (8), WJ (2), Pilates (1), Pilates + WJ (1), bicycling (1), RE (1), TCE (3), and AE + RE (1). The network plot in [Figure 3](#) shows that the most studies involved yoga versus UC and TCE versus UC, with 2 studies in each comparison. Based on the league table in [Figure 4](#), compared to usual care, Pilates had a MD of -2.17 cm (95% CI -3.77 to -2.57),

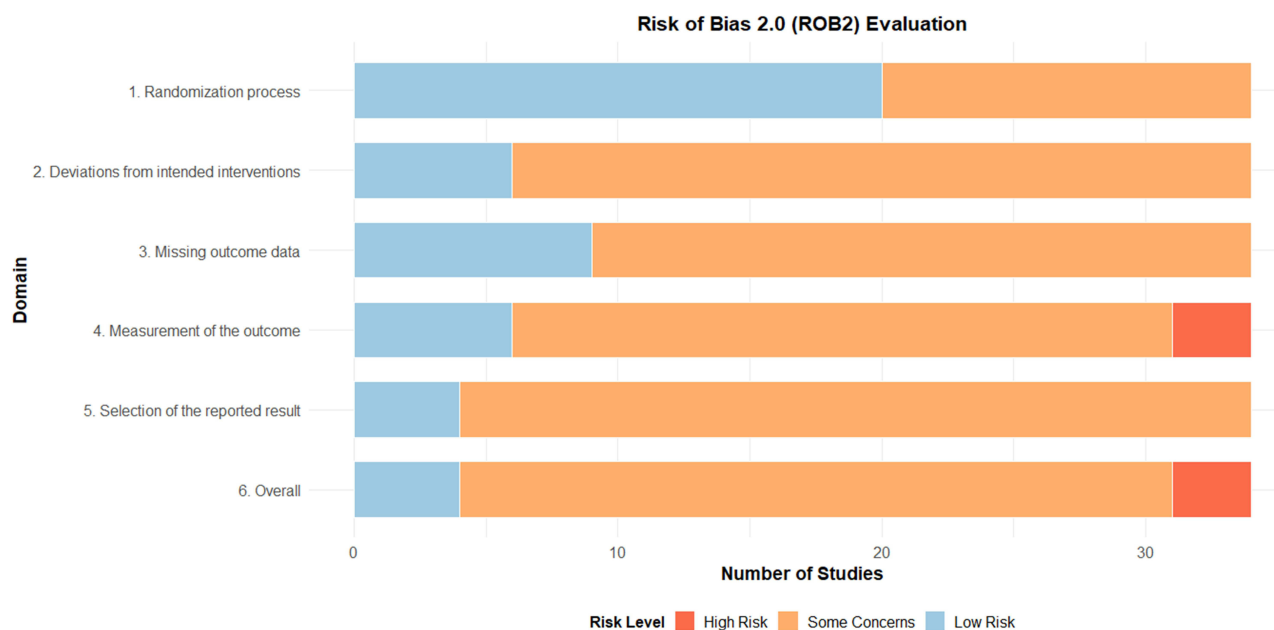


Figure 2 Overall summary risk of bias.

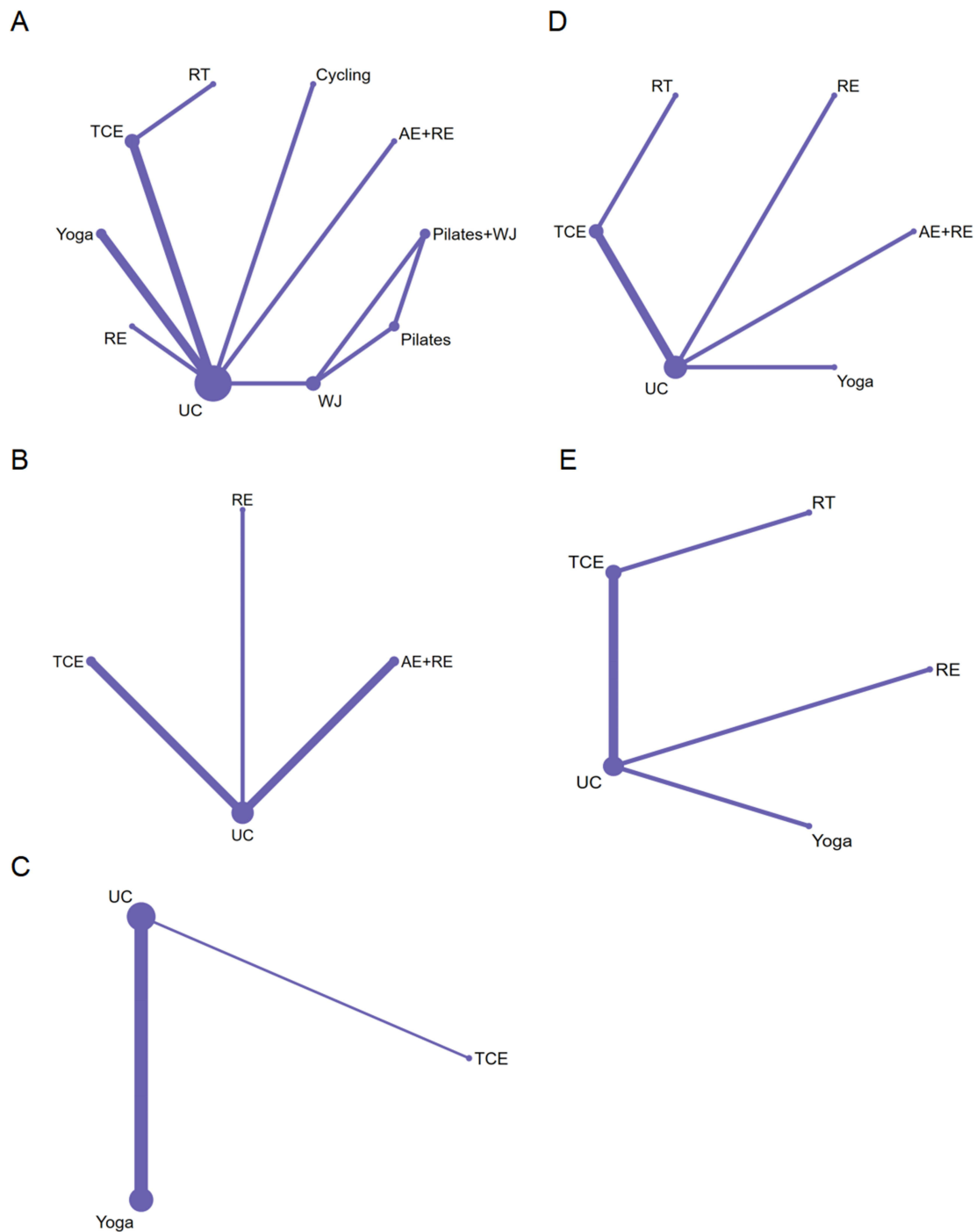


Figure 3 The network structure diagram for outcome measures. Each circle on the diagram represents a treatment, and its size reflects the number of studies evaluating that treatment. The lines connecting the circles indicate direct comparisons between treatments. The figure features five subfigures, each representing a different outcome: (A) VAS; (B), morning stiffness duration; (C) DAS28-ESR; (D) ESR; (E) CRP.

AE + RE MD = -1.67 cm (95% CI -2.17 to -1.17), WJ MD = -1.77 cm (95% CI -3.36 to -0.17), Pilates + WJ MD = -1.67 cm (95% CI -3.28 to -0.06), RE MD = -1.26 cm (95% CI -1.34 to -1.18), and TCE MD = -1.02 cm (95% CI -1.14 to -0.90). Compared to Pilates, WJ MD = -0.40 cm (95% CI -0.56 to -0.24), Pilates + WJ MD = -0.50 cm (95% CI -0.68 to -0.32); compared to TCE, AE + RE MD = -0.65 cm (95% CI -1.17 to -0.13), Pilates + WJ MD = -0.24 cm (95% CI -0.38 to -0.10). All of these comparisons were statistically significant ($P < 0.05$). The interventions were

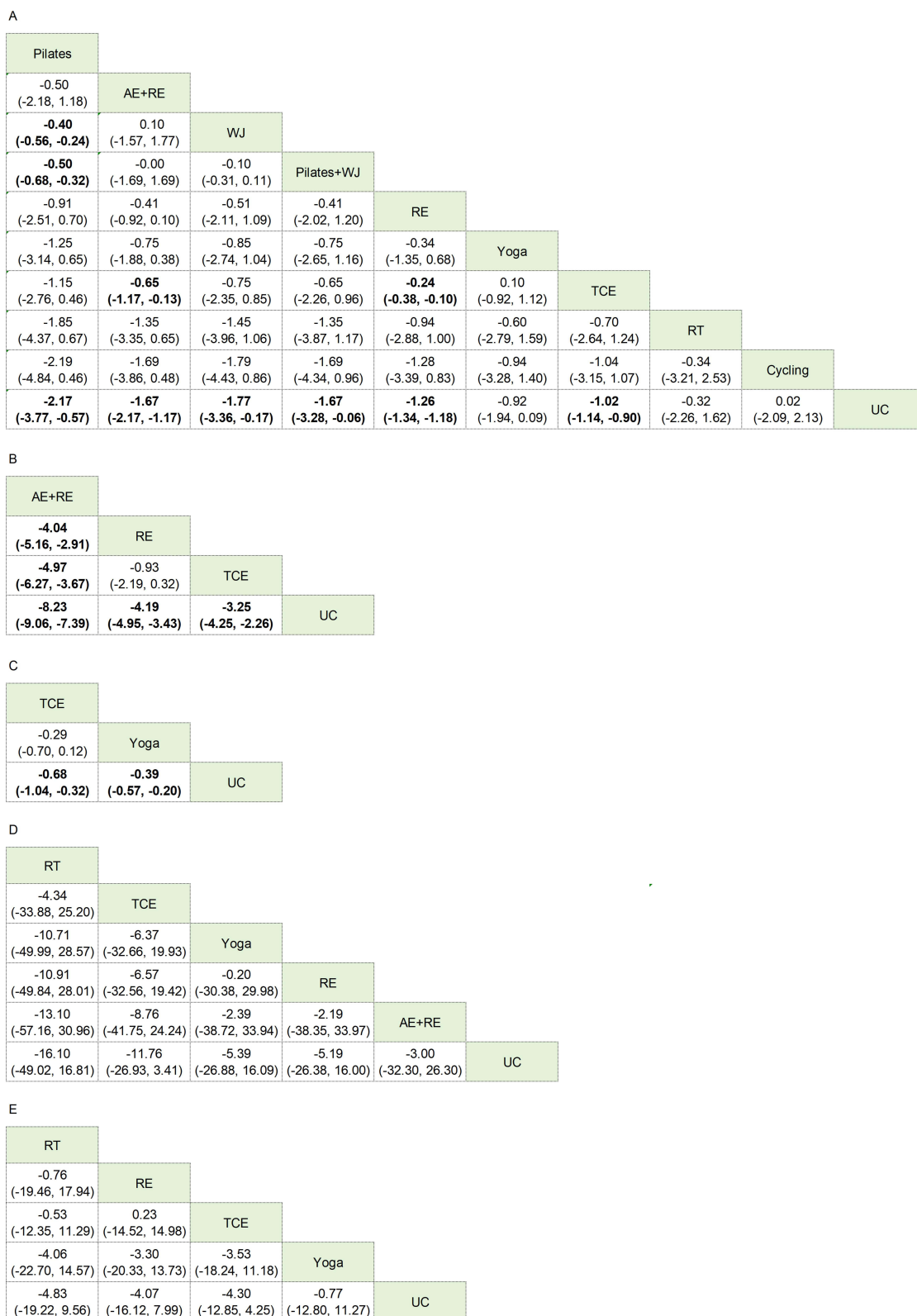


Figure 4 Relative effect analysis of outcomes. Cells filled with green in the table represent treatment measures. **(A)** VAS; **(B)** morning stiffness duration; **(C)**, DAS28-ESR; **(D)** ESR; **(E)** CRP. Additionally, each exercise therapy is identified as follows: AE+ RE, Aerobic Exercise + Resistance Exercise; WJ, Walking Or Jogging; Pilates+WJ, Pilates + Walking Or Jogging; RE, Resistance Exercise; TCE, Traditional Chinese Exercise; UC, Usual care. Statistically significant results were in bold.

ranked according to SUCRA values as follows: Pilates (91.8%) > AE + RE (76.8%) > WJ (72.2%) > Pilates + WJ (62.8%) > RE (57.8%) > yoga (42.3%) > TCE (40.4%) > RT (26.3%) > cycling (19%) > UC (10.7%), as shown in [Table S3.1](#) and [Figure S2.1](#).

MS Duration

MS duration was reported by 5 studies,^{38,42,44,46,61} with 1 study in which the treatment measure was RE, 2 studies in TCE, 2 studies in AE + RE, and 5 studies in UC. The network plot in [Figure 3](#) shows that the most studies involved AE + RE versus UC, and TCE versus UC, each with 2 studies. Based on the league table in [Figure 4](#), compared to UC, AE + RE had a MD of -8.23 minutes (95% CI -9.06 to -7.39), RE MD = -4.19 minutes (95% CI -4.95 to -3.43), and TCE MD = -3.25 minutes (95% CI -4.25 to -2.26). Compared to AE + RE, RE MD = -4.04 minutes (95% CI -5.16 to -2.91), and TCE MD = -4.97 minutes (95% CI -6.27 to -3.67). All comparisons were statistically significant ($P < 0.05$). The SUCRA probability ranking results ([Table S3.2](#) and [Figure S2.2](#)) indicated that AE + RE was the most effective intervention for reducing MS duration (100.0%), followed by RE (64.5%).

DAS28-ESR

Six studies^{23,26,41,49,51,54} reported DAS28-ESR outcomes. Among them, yoga was evaluated in five studies, UC in six studies, and TCE in one study. The netogram results ([Figure 3](#)) indicated that yoga was most frequently compared to UC (5 studies). According to the league table ([Figure 4](#)), compared to UC, TCE (MD = -0.68 scores, 95% CI: -1.04 to -0.32) and yoga (MD = -0.39 scores, 95% CI: -0.57 to -0.20) significantly improved DAS28-ESR ($P < 0.05$). Regarding DAS28-ESR improvement, TCE had the highest probability (SUCRA: 95.5%) of being the optimal intervention, followed by yoga (54.4%) and UC (0.0%) ([Table S3.3](#) and [Figure S2.3](#)).

ESR

ESR was elevated by 6^{16,37,42,54,61,64} studies involving 6 therapeutic measures including RT, yoga, UC, TCE, RE, and AE + RE. The netogram results ([Figure 3](#)) indicated that TCE was most frequently compared to UC (2 studies). According to the SUCRA values and cumulative probability ranking charts ([Table S3.4](#) and [Figure S2.4](#)), RT had the highest likelihood of effectively improving ESR (71.8%), followed by TCE (67.8%). All exercise interventions demonstrated superior efficacy compared to UC (25.6%).

CRP

Five studies^{38,42,54,61,62} reported CRP outcomes, evaluating five therapeutic interventions: RT (1 study), yoga (1 study), UC (4 studies), RE (1 study), and TCE (3 studies). The reticulation diagram ([Figure 3](#)) indicated that TCE was most frequently compared with UC (2 studies). According to the SUCRA values ([Table S3.5](#) and [Figure S2.5](#)), TCE had the highest probability of being the optimal intervention (62.7%), whereas UC had the lowest (28.0%).

Publication Bias

Comparison-corrected funnel plots were generated for each outcome measure ([Figure 5](#)). In all funnel plots, the included studies appeared approximately symmetrical around the midline, indicating a low probability of publication bias.

Certainty of Evidence

The evidentiary strength supporting the 3 key results—VAS, MS duration, and DAS28-ESR—was evaluated using the CINeMA framework. The majority of comparisons received a “very low” confidence assessment, while some were rated as “low.” Specifically for VAS, “low” confidence evidence was noted for the following comparisons: WJ versus Pilates, WJ versus Pilates + WJ, Pilates + WJ versus Pilates, UC versus Pilates, and UC versus Pilates + WJ. Similarly, comparative analyses between TCE and UC, and between TCE and yoga for the DAS28-ESR metric yielded “low” confidence levels. All remaining comparisons of treatments were deemed “very low” in confidence ([Table S4.1–4.3](#)).

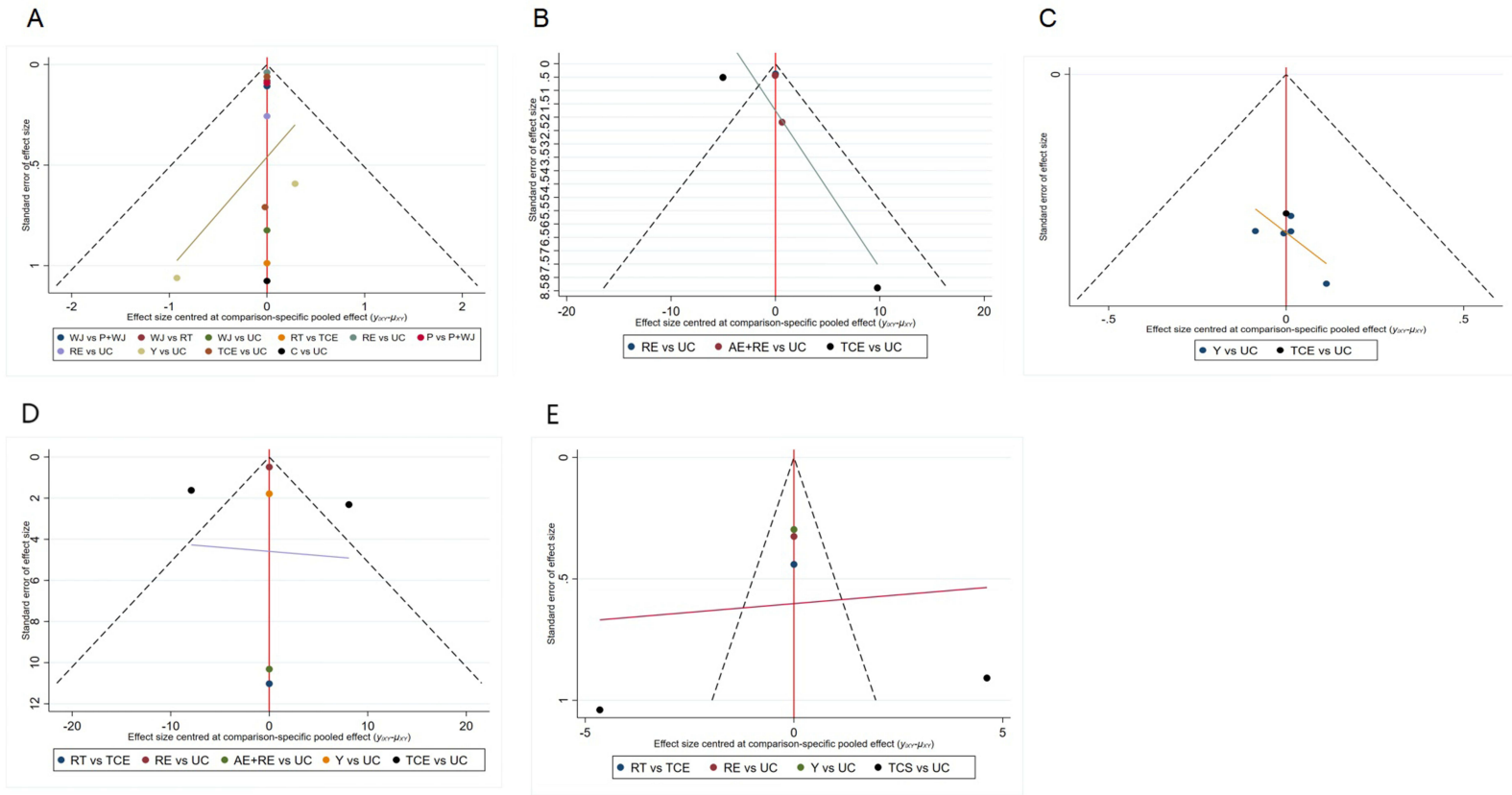


Figure 5 The funnel plot for all outcomes. **(A)** VAS; **(B)** morning stiffness duration; **(C)** DAS28-ESR; **(D)** ESR; **(E)** CRP. Additionally, each exercise therapy is identified as follows: P, Pilates; AE+RE, Aerobic Exercise + Resistance Exercise; WJ, Walking Or Jogging; P+WJ, Pilates + Walking Or Jogging; RE, Resistance Exercise; Y, Yoga; TCE, Traditional Chinese Exercise; RT, Relaxation Training; C, Cycling; UC, Usual care.

Discussion

RA ranks among the most prevalent autoimmune diseases worldwide. Current pharmacological treatments have limitations, including adverse effects. Exercise has been increasingly recognized as an important complementary treatment for RA. This study employed NMA to evaluate the clinical effectiveness of various exercise modalities, with the objective of providing evidence-informed recommendations for RA management. In total, 34 studies involving 10 exercise modalities and 2,435 patients with RA were included. The results indicated that six interventions—Pilates, AE + RE, WJ, Pilates + WJ, RE, and TCE—significantly improved VAS compared to UC, with Pilates ranked highest. For MS duration, AE + RE, RE, and TCE showed significant improvements compared with UC, with AE + RE ranked highest. Regarding DAS28-ESR, TCE and yoga demonstrated significant improvements compared with UC. SUCRA results indicated that TCE had the highest probability of being the optimal exercise modality. Although no intervention demonstrated statistically significant improvements in ESR and CRP compared with UC, SUCRA results suggested potential advantages of RT for ESR and TCE for CRP. According to the CINeMA framework, the overall confidence in the evidence was rated from low to very low.

Pilates is a form of exercise focusing on core stability training, encompassing posture, endurance, flexibility, and respiratory control.⁶⁵ Key goals entail boosting muscle strength and endurance, increasing flexibility and movement scope, optimizing balance and stance regulation, fostering respiratory health, and alleviating stress.⁶⁶ The included RCT evaluating Pilates for RA reported a reduction in pain intensity; however, VAS scores showed no statistically significant difference pre- and post-intervention within the Pilates cohort.⁴⁵ This result might be attributable to the lower baseline pain levels and disease activity among subjects. A larger sample size could potentially yield different conclusions. In an 8-week study conducted by Khalili et al, Pilates notably lessened VAS scores within the treatment cohort; conversely, the control group showed negligible change.⁶⁷ Additionally, Pilates has been shown to relieve pain in patients with various other rheumatic conditions, including fibromyalgia, ankylosing spondylitis, and juvenile idiopathic arthritis.^{68–70} The SUCRA results from this study indicated that Pilates + AE was less effective in improving VAS scores compared to Pilates alone. This may be attributed to the higher exercise load of the combined regimen, increasing joint burden and subsequently reducing efficacy. Basic experimental studies have demonstrated that moderate-intensity exercise interventions yield superior outcomes compared to high-intensity exercises in inhibiting inflammation, maintaining articular cartilage homeostasis, and promoting metabolic responses in joint tissues.^{71,72} Chronic pain in RA is influenced by both peripheral and central nervous system factors.¹¹ Exercise interventions, including Pilates, may alleviate pain through various mechanisms. These mechanisms include improving circulation to the joints, reducing muscle stiffness, and modulating immune function.⁷³ Studies indicate that exercise may also reduce inflammation by decreasing pro-inflammatory cytokine levels.⁵⁴ Additionally, exercise may have neurophysiological effects, such as altering central pain processing, which can reduce pain perception over time. Yoga has also been shown to significantly reduce pain in RA patients.^{74,75} Effective pain management in RA patients is beneficial for improving physical functioning and enhancing psychological well-being. Chronic pain can worsen anxiety, depressive symptoms,⁷⁶ and sleep disturbances,⁷⁷ leading to a decrease in overall quality of life. Joint stiffness frequently occurs in RA patients following periods of rest and is typically most pronounced in the morning, termed MS. In clinical studies of RA, the MS duration is commonly utilized as an indicator of disease severity.⁷⁸ The occurrence of MS is primarily associated with increased levels of key pro-inflammatory cytokines, such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF- α).⁷⁹ A clinical study demonstrated a significant reduction in IL-6 levels among RA patients following ten sessions of combined aerobic and resistance exercise.⁸⁰ Another animal study also observed reduced expression of TNF- α mRNA in RA rats subjected to AE, RE, or their combination compared to controls. Notably, the combined exercise group showed lower TNF- α mRNA expression than either single-exercise group.⁷² Both studies indirectly suggest that combined aerobic and resistance exercise may help reduce MS duration in RA patients.

Our NMA has several strengths. First, this is the first NMA evaluating exercise interventions for patients with RA. Second, we conducted a comprehensive literature search and established predefined inclusion criteria to minimize clinical heterogeneity. Based on published RCTs, we included ten common exercise modalities used in the management of RA. Funnel plots were utilized for evaluating the presence of publication bias. We ranked each intervention using the SUCRA

probability values and conducted statistical analyses to determine significant differences among interventions. This NMA's execution followed the PRISMA-NMA protocol. Moreover, CINeMA was employed to assess the certainty of evidence when comparing various interventions on individual outcome metrics.

However, several limitations exist in this study. First, due to the nature of exercise interventions, participants were aware of their allocated treatments, rendering double-blind trials infeasible. Additionally, some included studies lacked investigator blinding, potentially introducing detection bias. Second, the sample size of the included studies was relatively limited, even if no significant funnel plot asymmetry was found, but this may have limited the ability to completely rule out publication bias. The small number of studies for each intervention also limits the representativeness of some interventions to specific outcomes and thus reduces the comprehensiveness of effect estimates. Third, although this study compared the relative efficacy of various exercise modalities, it did not examine the ideal interplay between exercise intensity, frequency, and duration. Thus, subsequent research should incorporate robust, extensive RCTs featuring extended longitudinal monitoring to further validate the sustained benefits of exercise interventions in RA patients. Additionally, individualized exercise prescriptions should be further explored to offer precise intervention strategies for RA patients with varying disease durations and severity levels.

Conclusion

Exercise interventions provide beneficial effects for RA patients. Pilates appears to be the optimal exercise modality for improving VAS, AE + RE is potentially the most effective intervention for reducing MS duration, and TCE may provide the greatest improvement in DAS28-ESR. These results suggest selecting specific exercise modalities based on targeted clinical outcomes. Future high-quality RCTs with extended follow-up are needed to validate these results.

Data Sharing Statement

Source data for this study are available within this article/Supplementary Material. For more details, reach out to the corresponding author (Ligang Jie).

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Disclosure

The authors declare no conflicts of interest associated with this study.

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