Exercise therapy for spondyloarthritis: a systematic review

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REVIEW ARTICLE

Exercise therapy for spondyloarthritis: a systematic review

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Abstract To evaluate the effects of therapeutic exercise on pain, stiffness, quality of life, physical function, disease activity, health-related fitness and cardiovascular risk factors in adults with spondyloarthritis (SpA). Electronic databases (Cochrane Central Register of Controlled Trials, EMBASE, MEDLINE/PubMed, PEDro, AMED, CINAHL) were systematically searched from inception to October 2013 using medical subject headings and keywords. This was supplemented by searching conference abstracts and a hand search of reference lists of included studies. Randomised and quasi-randomised studies of adults with SpA in which at least one of the comparison groups received an exercise intervention were included. Outcomes of interest were pain, stiffness, quality of life, physical function and disease activity. Secondary outcomes were health-related fitness and cardiovascular risk factors. Two reviewers independently screened studies for inclusion. Methodological quality was assessed by two reviewers using the Cochrane risk of bias tool and the PEDro scale. Twenty-four studies, involving 1,498 participants, were included. Meta-analyses were not undertaken due to clinical heterogeneity, and this review focuses on qualitative synthesis. Moderate evidence supports exercise interventions in improving physical function, disease activity and chest expansion compared to controls; there is low-level evidence of improved pain, stiffness, spinal mobility and cardiorespiratory function. Supervised group exercise yields better outcomes than unsupervised home exercise. The addition of aerobic components to flexibility programmes improves cardiorespiratory outcomes, but not cardiovascular risk factors. The most effective exercise protocol remains unclear. Current evidence suggests that therapeutic exercises are beneficial for adults with ankylosing spondylitis; effects on other SpA subtypes are unknown.

Keywords Ankylosing spondylitis · Spondyloarthritis · Exercise · Fitness · Cardiovascular risk

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Introduction

The spondyloarthropathies (SpA) are a heterogeneous group of inflammatory arthritides that include ankylosing spondylitis (AS), reactive arthritis (ReA), enteropathic spondylitis or arthritis associated with irritable bowel disease (IBD), psoriatic arthritis (PsA) and undifferentiated spondyloarthropathy (uSpA) [1]. They are characterised by sacroiliitis with inflammatory back pain, peripheral joint pain, enthesitis, dactylitis and extra-articular manifestations including uveitis, psoriasis and IBD. SpA are associated with decreased physical function and lower health-related quality of life (QoL) [2, 3]. Depending on clinical features and imaging, SpA can be classified as predominantly axial SpA or predominantly peripheral SpA [4, 5].

Current practice guidelines recommend a combination of pharmacological and non-pharmacological treatment modalities for optimal management of patients with AS and PsA [6, 7]. Exercise programmes have shown small

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but beneficial effects on spinal mobility and physical function in adults with AS [8]. To our knowledge, no review has systematically examined the effect of exercise in other SpA subtypes, although exercise is frequently advised as part of their management.

Epidemiological evidence suggests that AS and PsA are associated with elevated cardiovascular risk factors and increased cardiovascular morbidity and mortality [9, 10]; however, to date, studies have not explored the effects of therapeutic exercise on cardiovascular risk factors and physical fitness parameters in SpA. The aims of this review were to assess the effects of exercise on pain, stiffness, QoL, physical function, health-related fitness and cardiovascular risk factors in adults with SpA.

Materials and methods

A protocol outlining the review strategy and methods of analysis was registered with a registry of systematic reviews (available at http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42013004015).

Eligibility criteria

Adults diagnosed by a rheumatologist as having AS, ReA, PsA, uSpA or enteropathic spondylitis were included. Participants under 18 years of age or with juvenile-onset SpA were excluded. Quasi-randomised and randomised controlled trials (RCT) in which at least one of the groups received exercise therapy were included. Review articles, observational studies without controls, case reports, cross-sectional studies and commentaries were excluded.

For the purpose of this review, exercise-based interventions comprised one or more of the following components: range of motion (stretching), strengthening or aerobic exercise. Any dosages of exercise prescription (i.e. any frequency, intensity, mode or duration) were considered. However, interventions offering general advice to exercise without prescribing specific exercises were excluded. Exercise-based interventions delivered in an inpatient setting were excluded, unless being compared to a distinct outpatient exercise group. Studies in which exercise-based interventions were administered in conjunction with other modalities (e.g. manual therapy) were excluded.

The primary outcomes of interest to this review were pain, stiffness, disease activity, physical function and QoL. Secondary outcome variables were health-related fitness measures (cardiorespiratory, muscular strength, flexibility and body composition) and cardiovascular risk factors (blood pressure, glycaemia, metabolic syndrome, body mass index and lipid profile).

Information sources and study selection

Studies were retrieved by searching electronic databases (MEDLINE/PubMed, EMBASE, PEDro, AMED, CINAHL and The Cochrane Central Register of Controlled Trials) from their inception to October 2013. Search terms were adapted for use with each database. Common keywords and medical subject headings related to three components: (1) the condition (e.g. spondyloarthritis), (2) the intervention (e.g. exercise) and (3) the study design (e.g. clinical trial) (See Supplement 1). No search restrictions (date or language) were imposed. The electronic database search was supplemented by searching abstracts of the annual meetings of the World Confederation for Physical Therapy (2003–2011), the American College of Rheumatology (2006–2012), the European League Against Rheumatism (2002–2013) and the American Physical Therapy Association (2002–2013). When only abstracts were available in the published literature, authors were contacted seeking full texts of relevant studies. Finally, a hand search of the reference lists of included studies was conducted.

Two reviewers (TOD and FW) independently screened titles and abstracts to identify studies that potentially met the eligibility criteria. Full texts of these reports were retrieved and independently assessed for eligibility by the same two reviewers. Any disagreements on inclusion were resolved by discussion to achieve consensus, and failing agreement, a third reviewer (FOS) was consulted.

Data collection and analysis

A data extraction template based on Cochrane guidelines [11] was adapted and piloted on five randomly selected studies and modified accordingly. One reviewer (TOD) recorded (1) participant characteristics, (2) details of interventions and (3) relevant outcome data (group means and standard deviations). For continuous data, the differences in group means (with 95 % CI) were calculated at clinically relevant time points (i.e. post-intervention and at follow-up). For continuous data reported on different scales, standardised mean differences with 95 % CIs were used. The calculations employed a random effects model. In trials comparing two similar exercise groups and one control group, the exercise group results were pooled for comparative purposes [12, 13]. In the event that the published data from included studies were insufficient to calculate pooled effects, study authors were contacted requesting additional data. Meta-analyses were planned but ultimately deemed inappropriate due to the heterogeneity of study designs and interventions. Due to the absence of studies exploring the effects of exercise interventions on predominantly axial and predominantly peripheral SpA, this proposed subgroup analysis was not completed. Statistical analysis was conducted using Review Manager 5.2 and SPSS 21.

Risk of bias and levels of evidence

A risk of bias appraisal of included studies was performed independently by two reviewers (TOD and FW). Disagreements between the reviewers were resolved through discussion to achieve consensus. Failing agreement, a third reviewer (FOS) arbitrated. The Cochrane Collaboration's risk of bias tool rated risk of bias across six domains as low, high or unclear [11]. The Physiotherapy Evidence Database (PEDro) scale rated methodological quality from 0 (low) to 10 (high) [14]. Fair-to-good reliability has been established for the total PEDro score [15]. Each study was ascribed a level of evidence according to the criteria of the Oxford Centre for Evidence-based Medicine [16] (Table 1). These levels of evidence provide a hierarchy of the likely best evidence. Quality of evidence for key outcomes across comparisons was evaluated following the GRADE levels of evidence [17] (Table 2).

Results

Study selection

The electronic database search returned 450 records (after the removal of duplicates), and an additional nine reports were identified from the search of conference abstracts. One unpublished full-text report of a conference abstract was provided [18]; attempts to obtain full texts of other published abstracts from the authors were unsuccessful. The search strategy and selection process are summarised in Fig. 1. A total of 24 studies (18 RCT) published between 1993 and 2013 were included in this review.

Study characteristics

Study characteristics and findings are summarised in Table 3. A total of 1,460 participants with AS and 38 fulfilling the Amor criteria for SpA were included. No other SpA subtypes were examined in the included studies. The mean study sample size was 62 (SD 37; range 20–155). The ratio of participants was approximately 3:1 (male:female). Subject characteristics varied in age, disease duration, disease severity and medication use.

Exercise intervention duration ranged from 3 weeks [19] to 3 years [20]. Frequency of exercise varied from twice daily [19] to once weekly [21–23], with individual session duration ranging from 30 min [18, 24–29] to 3 h [13]. Traditional therapeutic exercises targeting flexibility, posture and respiration predominated. Other exercise protocols included aerobic exercise, strength training, proprioceptive exercise, the Global Posture Re-education (GPR) method, the Pilates method, hydrotherapy and sporting activities. Seven studies compared the effect of exercise to controls, twelve compared two or more types of exercise-based interventions, and five compared therapeutic exercise to another treatment modality (inpatient rehabilitation, balneotherapy, incentive spirometry or spa-exercise therapy).

Self-report measures of physical function, QoL, disease activity, pain and stiffness were identified as primary outcomes. Flexibility was the most commonly examined health-related fitness component; fewer studies examined cardiorespiratory fitness, while no studies examined body composition or muscular strength. Cardiovascular risk factors (cholesterol and triglycerides) were assessed in one study [29]. Follow-up measures were recorded in five studies [24, 30–33].

Table 1 Oxford Centre for Evidence-based Medicine 2011 levels of evidence

Level of evidence	Description
Level I	Systematic review of randomised trials or *n*-of-1 trials
Level II	Randomised trial or observational study with dramatic effect
Level III	Non-randomised controlled cohort/follow-up study
Level IV	Case–series, case–control or historically controlled studies
Level V	Mechanism-based reasoning

Table 2 GRADE levels of evidence

Quality level	Definition
High	We are confident that the true effect lies close to that of the estimate of the effect
Moderate	We are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is the possibility that it is substantially different
Low	Our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect
Very low	We have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect

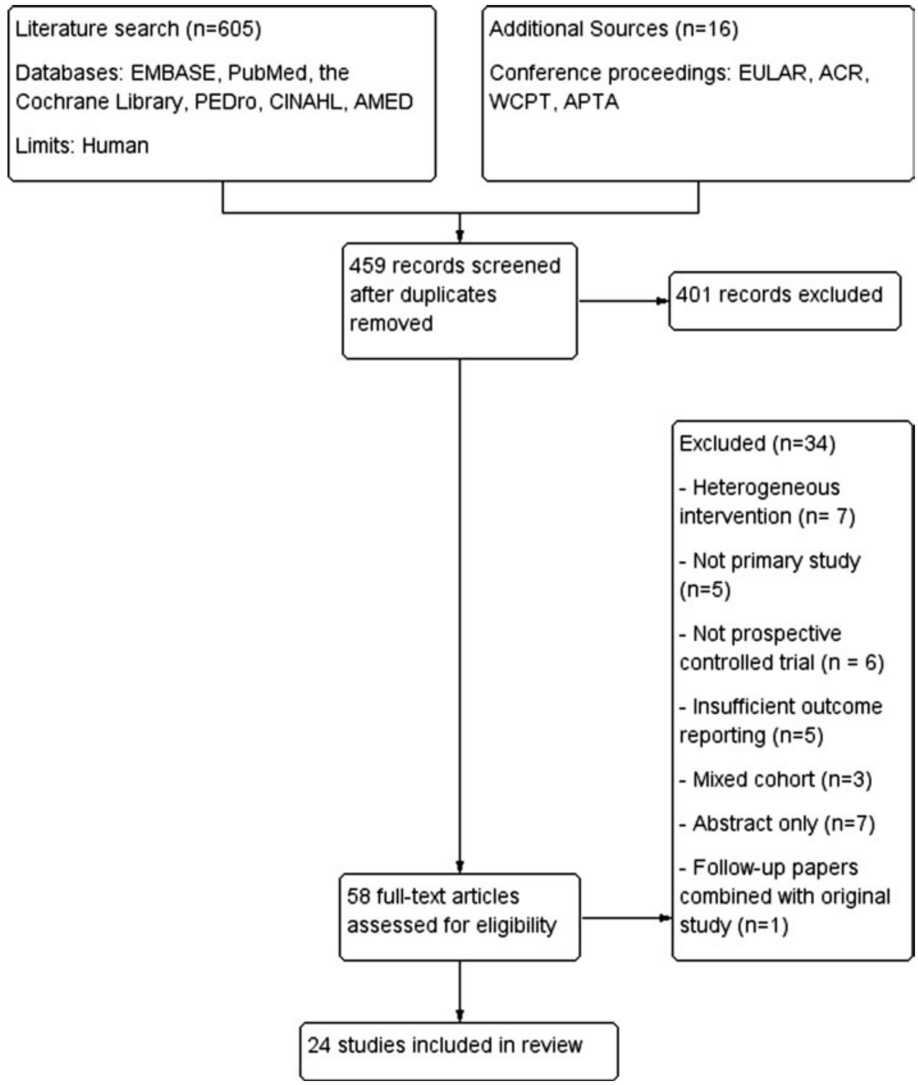


Fig. 1 PRISMA flow diagram of study selection process

Risk of bias within studies

The methodological quality of included studies was mixed (summarised in Fig. 2), with the overall risk of bias unclear. Seven studies were deemed to have a low risk of selection bias [13, 24, 25, 29–31, 34]. Six studies used methods other than randomisation to allocate participants to groups [12, 21–23, 26, 35]. There was a high risk of performance bias due to inherent difficulties in blinding participants to exercise-based treatments. Ten studies met the criteria for blinding of outcome assessment [19, 22, 24, 27–31, 33, 36], and five studies met the criteria for reporting outcome data [13, 19, 23, 29, 34]. Reporting bias across studies is generally low or unclear; only two studies preregistered their study protocols [25, 29]. The mean PEDro score of the 18 RCTs included was 5.8 (SD 1.4; range 4–8). The six non-randomised controlled trials had a mean PEDro score of 3.5 (SD 0.5; range 3–4) (Supplement 2).

Synthesis of results

This review focused on a qualitative synthesis of the studies. A meta-analysis was not undertaken due to the heterogeneity of study designs, participants, interventions and reported outcome measures. When sufficient data were reported, individual effect sizes were calculated and presented on forest plots to provide a visual overview of results. Study results are summarised in Table 3.

Comparison 1: therapeutic exercise compared to controls

Seven studies compared therapeutic exercise interventions with controls. Three of these examined home exercise programmes (HEP) [28, 35, 37], two implemented supervised group exercise (GE) [30, 36], and one study conducted Pilates training [34]. One three-armed study compared an unsupervised GPR programme to a HEP and to controls;

Table 3 Main characteristics and results of included studies

References; evidence level	*n* (male: female); condition Age (mean ± SD)	Intervention	Outcome measures	Significant between-group differences (MD [95 % CI])
Comparison 1: therapeutic exercise compared to controls				
Altan et al. [34]; level II	29; AS (mNYC) 46.5 ± 11.2	Pilates: 1 h, 3 days/week × 12 weeks	BASFI, ASQoL, BASDAI, BASMI, CE	Pilates > control in BASDAI 1.0 point [0–2.0]
	24; AS (mNYC) 43.6 ± 10.1	Control: standard care and usual physical activity		
Durmus et al. [12]; level III	25 (21:4); AS (mNYC) 37.3 ± 7.3	HEP: 20 exercises daily × 12 weeks; relaxation, flexibility, strength, respiratory exercise, posture, mobilisation, stretching	BASFI, SF-36, BASDAI	Unsupervised HEP > standard care for all outcomes. BASFI: 1.05 points [0.31–1.79], BASDAI: 0.99 points [0.43–1.55] and SF-36: all subscores favoured HEP ($p < 0.001$)
	18 (14:4); AS (mNYC) 42.3 ± 8	Control: standard care		
Durmus et al. [35]; level III	19 (17:2); AS (mNYC) 35.9 ± 7.3	HEP: 12 weeks, exercises dosage not specified; 20 exercises, mobilisation, stretching, respiratory exercise	BASFI, pain, BASDAI, CE, FVC, FEV1, PEF, VC, MVV, 6MWT	Exercise (pooled) > control for CE: 0.88 cm [0.2–1.53] and 6MWT: 83.5 m [23.48–143.52] No significant differences between the two exercise groups
	19 (14:5); AS (mNYC) 38.1 ± 11.1	Unsupervised GPR: 12 weeks, exercises dosage not specified; warm-up, mobilisation, stretching, posture, respiratory exercise		
	13 (12:1); AS (mNYC) 43.5 ± 7.3	Control: standard care		
Ince et al. [36]; level II	15 (9:6); AS (mNYC) 33.7 ± 5.2	Supervised GE: 50 min, 3 days/week × 3 months; multimodal programme of stretching, pulmonary exercise, step-exercise	CE, CCD, MST, OWD, FFD, VC, Physical work capacity Inclinometer: gross hip, lumbar and thoracic flexion	Supervised GE > control for CE: 1.46 cm [0.29–2.63], CCD: 1.88 cm [0.68–3.08], OWD: 2.56 cm [0.22–4.9], MST: 1.35 cm [0.14–2.56], gross thoracic flexion: 18.6° [8.55–28.65], physical work capacity: 0.69 W/kg [0.26–1.12] and VC: 13.24 % [2.66–23.8]
	15 (9:6); AS (mNYC) 36.1 ± 7.2	Control		
Lim et al. [28]; level II	25 (20:5); AS 28.1 ± 7.5	HEP: 30 min, daily × 8 weeks; 16 exercises, muscle relaxation, flexibility, strengthening, respiration, posture	FFD, BASFI, pain Inclinometer: cervical flex/ext, shoulder flex/abd, hip abd and knee flex	Mean (SD) not reported. Unsupervised HEP > control for inclinometer measurements ($p < 0.0001$), FFD ($p < 0.0001$), BASFI ($p < 0.0001$) and pain ($p < 0.0001$)
	25 (19:6); AS 28.8 ± 9.3	Control: waiting list		

Table 3 continued

References; evidence level	*n* (male: female); condition Age (mean ± SD)	Intervention	Outcome measures	Significant between-group differences (MD [95 % CI])
Masiero et al. [30]; level II	20 (15:5); AS (mNYC) Median age: 47.5	Rehabilitation group Education: Two 3-h educational–behavioural meetings + Supervised GE: 1 h, 2 days/week for 6 weeks; flexibility, stretching, proprioception, respiratory exercises + HEP: 3–4 times/week for 6 weeks	Pain (cervical, lumbar), CE, BASMI, BASDAI, BASFI, MS, Spinal mobility (goniometry): cervical flex/ext/rotation/lateral inclination, lumbo-sacral flex/ext, thoraco-lumbar rotation/lateral inclination	Mean (SD) not reported Post-intervention: Rehab > control in all measures ($p < 0.05$) except cervical flex/ext ($p = 0.08$) Rehab > education for CE ($p = 0.004$) and spinal mobility ($p < 0.05$) except cervical flex/ext ($p = 0.428$) Six-month follow-up: Rehab > control in all measures ($p < 0.05$) except cervical flex/ext ($p = 0.175$) Rehab > education for BASDAI ($p = 0.05$), BASMI ($p = 0.033$), CE ($p < 0.0005$) and spinal mobility ($p < 0.05$) except cervical flex/ext ($p = 0.428$) Education group > control for BASFI ($p = 0.002$)
	20 (16:4); AS (mNYC) Median age: 44.0	Education group Education: as above		
	22 (18:4); AS (mNYC) Median age: 47.5	Control		
Sweeney et al. [37]; level II	75 (51:24); AS 46.5	HEP: mail-delivered exercise package (video, booklet, exercise wall chart) for 6 months	BASFI, BASDAI	No significant between-group differences
	80 (53:27); AS 45.9	Control		
Comparison 2.1: unsupervised home exercise compared to supervised group exercise				
Analay et al. [31]; level II	23 (20:3); AS (Amor) 37.6 ± 11.3	Supervised GE: 50 min, 3 days/week for 6 weeks; stretching, mobilisation, strengthening, aerobic, postural and respiratory exercises	Pain (rest), pain (activity), MS, CE, TWD, MST, FFD, IMD, VO_{2MAX}, BASFI	No significant between-group differences post-intervention or at 3-month follow-up
	22 (18:4); AS (Amor) 34.3 ± 7.9	HEP: 50 min, 3 days/week for 6 weeks; stretching, mobilisation, strengthening, aerobic, postural and respiratory exercises		

Table 3 continued

References; evidence level	*n* (male: female); condition Age (mean ± SD)	Intervention	Outcome measures	Significant between-group differences (MD [95 % CI])
Cagliyan et al. [32]; level II	23 (18:5); AS (mNYC) 35.2 ± 7.8	HEP for 12 weeks (dosage not specified); mobilisation, stretching, respiratory and postural exercises	Pain (rest), pain (activity), stiffness, CE, lumbar side flexion, MST, dorsal Schober, FFD, IMD, OWD, cervical rotation, BASFI, BASDAI, SF-36	Post-intervention: HEP > GE for FFD: 9 cm [1.01–16.97] and CE (figures not reported) GE > HEP for IMD: 16.8 cm [1.29–32.31], BASFI: 0.62 points [0.03–1.21], BASDAI: 1 point [0.16–1.84], SF-36 physical function: 15 points [4.99–25.01], SF-36 physical role difficulty: 25 points [4.83–45.17] and SF-36 mental health: 10.8 points [0.52–21.08] 3-month follow-up: GE > HEP for BASFI: 0.63 points [0.04–1.22] and SF-36 physical role difficulty: 22.8 points [1.57–44.03]
	23 (20:3); AS (mNYC) 36.8 ± 9.4	Supervised GE: 1 h, 2 days/week for 12 weeks; mobilisation, stretching, respiratory and postural exercises		
Hidding et al. [27]; level II	76 (63:13); AS (mNYC) 41.5 ± 10.3 years	HEP: 30 min daily for 9 months; exercise directed at hip, peripheral joints and entire spine	Thoraco-lumbar flex/ext, CE, cervical rotation, maximum work capacity by ergometry, Sickness Impact Profile, HAQ-S, AS Functional Index, pain, stiffness	Post-intervention differences in change score reported GE > HEP for thoraco-lumbar flex/ext: 0.41 cm [0.1–0.7], work capacity: 8.9 W [0.0–17.6] and HAQ-S: 0.05 points [0.0–0.11]
	68 (49:19); AS (mNYC) 43.7 ± 10.4 years	HEP: as above + supervised GE: 1 day/week for 9 months; 1-h exercise, 1-h sports (volleyball or badminton) and 1-h hydrotherapy		
Karapolat et al. [26]; level III	22 (15:7); AS (mNYC) 47.5 ± 11.8 years	Supervised GE: 45 min, 3 days/week for 6 weeks; 10-min walk, respiratory, stretching, mobilisation and strengthening exercises	BASMI, BASFI, BASDAI, NHP	Supervised GE > HEP for NHP sleep subscore: 17.85 points [1.19–34.51]
	16 (11:5); AS (mNYC) 46.6 ± 14.8 years	HEP: 45 min, 3 days/week for 6 weeks; same as GE programme		
Ramos-Solchaga et al. [20]; level II	24 (18:6); AS (mNYC) 39.7 ± 10.7 years	Supervised GE: 30 min, 3 days/week for 3 years	CCD, CE, FFD, MST	No significant between-group differences reported
	35 (27:8); AS (mNYC) 36.6 ± 10.5 years	Supervised individual exercise: 20 × 30 min sessions within 1 month (annually) + unsupervised HEP rest of the 3 years		

Table 3 continued

References; evidence level	*n* (male: female); condition Age (mean ± SD)	Intervention	Outcome measures	Significant between-group differences (MD [95 % CI])
	41 (27:14); AS (mNYC) 34.4 ± 9.2 years	HEP for 3 years		
Comparison 2.2: global postural re-education				
Alonso-Blanco et al. [22]; level III	10 (9:1); AS (mNYC) Mean age: 51 ± 7 years	GPR protocol: 1 days/week for 12 weeks	FVC, FEV1, FEV1/FVC, CE	No significant between-group differences reported
	10 (9:1); AS (mNYC) Mean age: 54 ± 6 years	Supervised GE: 1 days/week for 12 weeks; spinal mobilisation, stretching, breathing		
Fernandez-de-las-Penas et al. [33]; level II	20 (16:4); AS (mNYC) 46 ± 8	Supervised GE: 1 h weekly for 15 weeks; monthly thereafter for 12 months + HEP; 20 exercises: mobilisation, stretching, breathing	TWD, MST, cervical rotation, lumbar side flexion, IMD, BASFI, BASDAI	No significant between-group differences reported after intervention or at 12-month follow-up
	20 (15:5); AS (mNYC) 45 ± 9	Group GPR: 1 h weekly for 15 weeks; monthly thereafter for 12 months supplemented by HEP; warm-up, mobilisation, stretching, postural exercise, respiratory exercise		
Rivera-Navarro et al. [21]; level III	12 (11:1); AS (mNYC) 49.8 ± 4.6	Supervised GE: 1 days/week for 16 weeks; mobilisation and stretching	SF-36	No significant between-group differences reported
	17 (13:4); AS (mNYC) 46.4 ± 7.4	Group GPR: 1 day/week for 16 weeks; warm-up, mobilisation, stretching, postural exercise, respiratory exercise		
Silva et al. [23]; level III	20 (14:6); AS (mNYC) 35.3 ± 12.2	Individual supervised GPR: 1 h/week for 16 weeks	Pain (cervical, dorsal, lumbar), MS, CCD, OWD, cervical rotation, FFD, MST, CE, BASDAI, HAQ-S, SF-36	Individual GPR > supervised GE for dorsal pain: 1 point [0.8–1.2], lumbar pain: 0.9 points [0.51–1.29], MS: 19.9 min [18.2–21.58], CCD: 1.7 cm [1.3–1.7], OWD: 3 cm [2.53–3.47], cervical rotation: 11.1° [10.44–11.76], MST: 0.3 cm [0.05–0.55], CE: 1.4 cm [1.19–1.61] and SF-36 physical aspects: 9.4 points [7.68–11.12]
	15 (12:3); AS (mNYC) 44.3 ± 10.6	Supervised GE: 40 min, 2 days/week for 16 weeks; segmental stretching, respiratory exercises		

Table 3 continued

References; evidence level	*n* (male: female); condition Age (mean ± SD)	Intervention	Outcome measures	Significant between-group differences (MD [95 % CI])
Comparison 2.3: aerobic exercise				
Karapolat et al. [38]; level II	13 (10:3); AS (mNYC) 50.2 ± 12.4	Swimming: free-style, 30 min, 3 days/week for 6 weeks; 60–70 % HRR-12 bpm + HEP: 30 min, 6 days/week for 6 weeks; flexibility, stretching, respiratory exercise	BASMI, CE, FFD, BASDAI, BASFI, NHP, 6MWT, pVO2, RER, AT, FEV1, FVC, FEV1/FVC, VC	Swimming + HEP > HEP for 6MWT: 60.17 m [28.79–91.55]
	12 (8:4); AS (mNYC) 46.9 ± 13.4	Walking: 30 min, 3 days/week for 6 weeks; 60–70 % pVO2, 13–15 on the Borg scale and 60–70 % HRR + HEP: as above		
	12 (9:3); AS (mNYC) 48.4 ± 9.5	HEP: as above		
Niedermann et al. [29]; level II	53 (34:19); AS (mNYC) 50.1 ± 11.9	Cardiovascular training: supervised Nordic walking, 30 min, 2 days/week for 6 weeks; intensity 55-85 % HR_{max} + unsupervised aerobic exercise (Nordic walking or other endurance activity), minimum 1 days/week for 12 weeks; intensity 55–85 % HR_{max} + Supervised GE: 1 h, 1 days/week for 12 weeks; focus on spinal flexibility	Physical work capacity, BASDAI, BASFI, BASMI, EURO-Quol, ESR, CRP, cholesterol and triglycerides	Cardiovascular training group > attention control group for PWC: 20.2 W [18.71–21.69]
	53 (34:19); AS (mNYC) 47.6 ± 12.4	Attention control: 2.5 h, 1 day/month for 12 weeks; discussion on coping strategies and stress reduction + Supervised GE: as above		
Comparison 2.4: multimodal exercise programmes				
Rosu et al. [39]; level II	48 (39:11); AS (mNYC) 25.3 ± 3.7	HEP: 50 min, 3 days/week for 48 weeks; mixed Pilates, Heckscher and McKenzie methods' exercises for breathing, posture	Pain, BASDAI, BASFI, BASMI, MST, FFD, CE, VC	Mixed Pilates, Heckscher and McKenzie methods HEP > multimodal HEP for pain: 7.5 mm [4.16–10.84], BASDAI: 2.0 points [1.5–2.6], BASFI: 1.3 points [0.7–1.8], BASMI: 1.8 points [1.6–2.1], MST: 1.1 cm [0.8–1.3], FFD: 7.8 cm [5.4–10.2], CE: 1.49 cm [1.2–1.8] and VC: 4.3 %predicted [1.1–7.6]

Table 3 continued

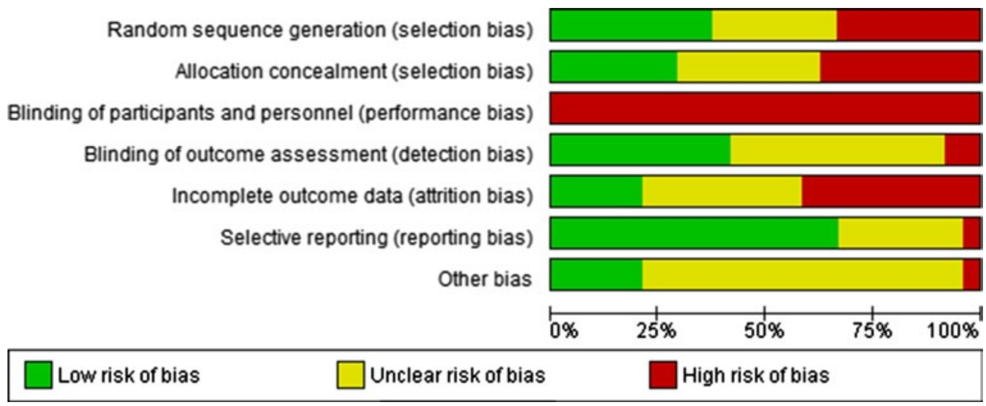
References; evidence level	*n* (male: female); condition Age (mean ± SD)	Intervention	Outcome measures	Significant between-group differences (MD [95 % CI])
	48 (40:8); AS (mNYC) 25.0 ± 3.8	HEP: 50 min, 3 days/week for 48 weeks; multimodal programme of stretching, pulmonary exercise, step-exercise		
Comparison 3.1: inpatient rehabilitation				
Figen et al. [19]; level II	*n* = 29 (24:5); AS (mNYC) 42.5 ± 10.6	Inpatient rehab: 15 sessions, over 3 weeks; physical therapy modalities, occupational therapy, therapeutic exercise. Education and exercise and activity advice	BASDAI, BASFI	No significant between-group differences
	n = 31 (20:11); AS (mNYC) 37 ± 9.6	HEP: twice daily for 3 weeks; postural, respiratory and stretching exercises, walking endurance, mobilisation. Education and exercise and activity advice		
Will et al. [18]; unpublished; level II	21 (14:7); SpA (Amor) 42.4 ± 12.2	Intensive exercise: live-in 5 days/week for 3 weeks (90-h exercise); group and individual stretching, gym exercises, hydrotherapy, aerobic fitness + HEP: 30 min daily for 12 months; stretching	BASDAI, BASFI, BASMI, CRP	No significant between-group differences
	17 (10:7); SpA (Amor) 42.9 ± 13.3	Light-intensity exercise: 2 h, 2 days/week for 3 weeks; 1-h gym exercise and 1-h hydrotherapy + HEP: 30-min daily stretching for 12 months		
Comparison 3.2: Balneotherapy				
Altan et al. [24]; level II	*n* = 28; age and gender not reported	Balneotherapy: 30 min daily for 3 weeks + HEP: 30 min daily for 6 months	Pain (daily), pain (night), MS, BASDAI, BASFI, DFI, NHP, OWD, CCD, CE, MST, FFibD	Post-intervention: Balneotherapy + HEP > HEP for BASDAI: 0.67 points [0.2–1.14] and NHP total: 53.01 points [4.84–101.2] No significant between-group differences at 6-month follow-up
	n = 26 age and gender not reported	HEP: 30 min daily for 6 months		
Comparison 3.3: incentive spirometry				
So et al. [25]; level II	23 (22:1); AS (mNYC) 38.0 ± 9.1	HEP: 30 min daily for 16 weeks; (20 exercises) mobilisation, stretching, breathing exercise	BASFI, BASDAI, CE, FFD 6MWT PFT: FVC, FEV1, FEV1/FVC, TLC, VC, RV	No significant between-group differences

Table 3 continued

References; evidence level	*n* (male: female); condition Age (mean ± SD)	Intervention	Outcome measures	Significant between-group differences (MD [95 % CI])
	23 (22:1); AS (mNYC) 34.6 ± 5.9	HEP: as above + incentive spirometry for 30 min daily for 16 weeks		
Comparison 3.4: Spa-exercise				
Van Tubergen et al. [13]; level II	40 (25:15); AS (mNYC) 48 ± 10	Spa-exercise (Austria): 5 days/week for 3 weeks; morning—1-h GE, 30-min walking, 14–30-min postural correction afternoon—alternating: 1-h visit to Gasteiner Heilstollen, or 30-min hydrotherapy, 30-min thermal bathing and 1-h sports + Supervised GE (when spa-exercise therapy concluded) 3 h, 1 days/week for 37 weeks; 1-h GE, 1-h sports, 1-h hydrotherapy	BASFI, pain, pain (night), ASQoL, MS, BASDAI, HAQ-S	Spa-exercise +GE (pooled results) > GE At 4 weeks: pain 1.1 points [0.12–2.01] and HAQ-S 0.42 points [0.03–0.8] At 16 weeks: pain 1.1 points [0.15–2.05] At 28 or 40 weeks no significant between-group differences
	40 (28:12); AS (mNYC) 49 ± 9	Spa-exercise (the Netherlands): 5 days/week for 3 weeks; morning—1-h GE, 30-min walking, 14–30-min postural correction afternoon—alternating: 2 × 15 min sauna + 30-min thermal bathing, or 30-min hydrotherapy, 30-min thermal bathing and 1-h sports + Supervised GE (when spa-exercise therapy concluded) 3 h, 1 day/week for 37 weeks; 1-h GE, 1-h sports, 1-h hydrotherapy		
	40 (34:6); AS (mNYC) 48 ± 10	Supervised GE: 1 day/week for 40 weeks; 1-h GE, 1-h sports, 1-h hydrotherapy		

abd abduction, *AS* ankylosing spondylitis, *ASQoL* Ankylosing Spondylitis Quality of Life, *AT* anaerobic threshold, *BASDAI* Bath Ankylosing Spondylitis Disease Activity Index, *BASFI* Bath Ankylosing Spondylitis Functional Index, *BASMI* Bath Ankylosing Spondylitis Metrology Index, *CCD* chin-to-chest distance, *CE* chest expansion, *CI* confidence interval, *CRP* C-reactive protein, *DFI* Dougados Functional Index, *ESR* erythrocyte sedimentation rate, *ext* extension, *FEV1* forced expiratory volume in 1 s, *FFD* finger-to-floor distance, *FFibD* fingertip-fibula head distance, *flex* flexion, *FVC* forced vital capacity, *GE* group exercise, *GPR* global postural re-education, *HAQ-S* Health Assessment Questionnaire for Spondyloarthropathies, *HEP* home exercise programme, *IMD* intermalleolar distance, *mNYC* modified New York criteria, *MS* morning stiffness, *MST* modified Schober's test, *MVV* maximal voluntary ventilation, *NHP* Nottingham Health Profile, *OWD* occiput-to-wall distance, *PEF* peak expiratory flow, pVO_2 maximal oxygen consumption, *RER* respiratory exchange ratio, *RV* residual volume, *SD* standard deviation, *SF-36* 36-item short-form survey, *TLC* total lung capacity, *TWD* tragus-to-wall distance, *VC* vital capacity, *6MWT* 6-min walk test

Fig. 2 Risk of bias of included studies



results from both exercise groups were pooled for comparison with controls [12].

Function, QoL, disease activity, pain and stiffness

Physical function was measured using the Bath Ankylosing Spondylitis Functional Index (BASFI) in six of the seven studies. Four of these are presented in Fig. 3; only the study by Durmus et al. [35] significantly favoured exercise. The other two studies did not report mean and standard deviations and are not included in the figure; their findings favoured exercise over controls [28, 30]. Benefits were maintained at 6-month follow-up [30].

The results of four studies measuring disease activity on the Bath Ankylosing Spondylitis Disease Activity Index (BASDAI) are presented in Fig. 3; the study by Durmus et al. [35] significantly favoured the exercise group. Masiero et al. [30] also found BASDAI scores to be significantly improved immediately after GE, and at 6-month follow-up, compared to controls. Compared to controls, spinal mobility scores on the Bath Ankylosing Spondylitis Metrology Index (BASMI) were significantly lower following a rehabilitation programme [30], but not significantly different after a Pilates intervention [34].

In comparison with controls, QoL was significantly improved following a HEP [35], but not following a Pilates-based intervention [34]. Pain and stiffness scores were significantly lower following exercise interventions and at 6-month follow-up [28, 30].

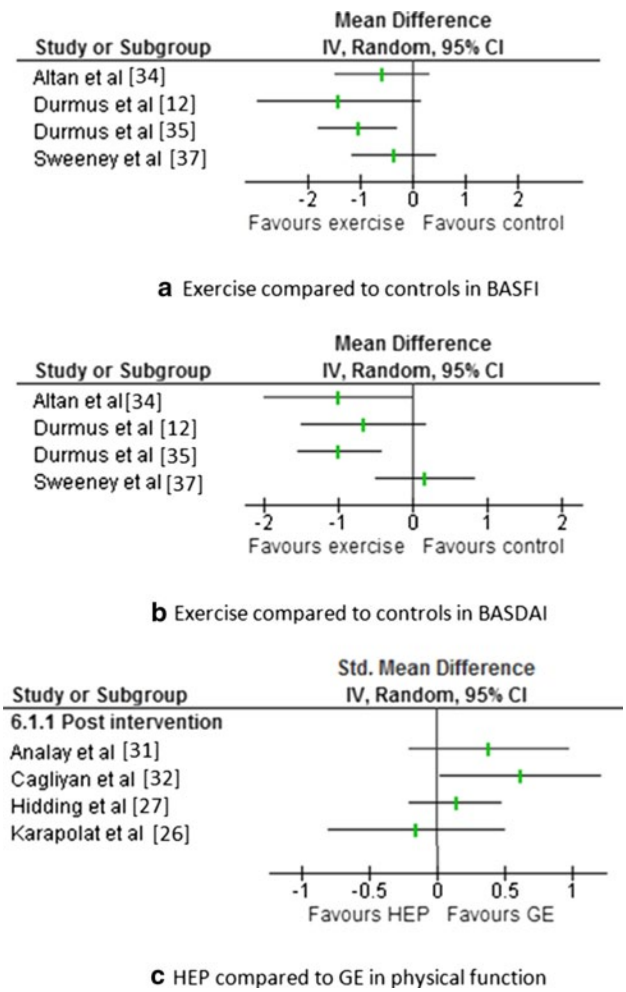


Fig. 3 Forest plot of between-group comparisons. *Std* standardised

Health-related fitness outcomes

Following a 3-month multimodal GE intervention, a significant improvement was observed in physical work capacity on a bicycle ergometer and predicted vital capacity [36]. Durmus et al. [12] reported a significant increase in distance walked in a 6-min walk test (6MWT) following exercise compared to controls; no significant between-group differences were observed in pulmonary function tests (PFTs).

The majority of individual mobility tests were significantly improved after exercise compared to controls [28, 36]. Inclinometer and pocket goniometry assessment found significant improvements favouring exercise groups in cervical, shoulder and knee range of motion (ROM), but results for thoraco-lumbar mobility were conflicting [28, 30, 36]. Chest expansion (CE) was significantly greater in a HEP group [12], a group undergoing a multimodal intervention [36], a rehabilitation group [30], but not in a Pilates group [34], compared to controls.

Therapeutic exercise is effective for improving physical function, disease activity and CE compared to controls, and the level of evidence is moderate coming from six, five and four studies, respectively. Exercise programmes are effective at improving joint mobility, cardiorespiratory function, pain and stiffness, and the level of evidence is low. There is conflicting evidence as to the effect of therapeutic exercise on QoL.

Comparison 2.1: unsupervised HEP compared to supervised GE

Three studies compared the effectiveness of unsupervised HEP with supervised GE [26, 31, 32]. One study evaluated the effects of adding weekly GE to a HEP [27]. One three-armed study compared regular supervised GE, infrequent supervised individual exercise supplemented with a HEP and unsupervised HEP [20].

Function, QoL, disease activity, pain and stiffness

Physical function was assessed in four studies using different outcome measures (Fig. 3). Cagliyan et al. [32] found a significant difference favouring the GE, which was maintained at 3-month follow-up. They also found that QoL significantly favoured GE immediately after a 3-month intervention; only physical role difficulty subscore remained significantly superior at follow-up. Karapolat et al. [26] found GE to be equivalent to HEP in QoL, except in the sleep subscore in which GE was significantly superior.

Disease activity (BASDAI) was significantly lower following GE compared to HEP in the study by Cagliyan et al. [32]; however, Karapolat et al. [26] found no significant between-group differences. The effects of GE and HEP on resting pain, pain during activities and duration of morning stiffness were comparable [27, 31, 32].

Health-related fitness outcomes

No intergroup differences in spinal mobility were found across a variety of measures [20, 26, 31]. Cagliyan et al. [32] found that CE and finger-to-floor distance favoured HEP over GE, whereas intermalleolar distance was superior following GE; no differences were found at follow-up. Thoraco-lumbar flexion/extension was significantly superior following the addition of weekly GE to a HEP compared to HEP alone. Cervical rotation and CE were similar across groups [20, 27].

Hidding et al. [27] measured aerobic power with a maximal, incremental exercise test on a cycle ergometer. Maximum workload was significantly higher following GE compared to HEP. Analay et al. [31] compared VO_{2MAX} values obtained by the Åstrand test and found no significant between-group differences after exercise interventions or at follow-up.

Group exercise is more beneficial than HEP in improving QoL, and the level of evidence is moderate coming from two studies. There is no difference between supervised GE and HEP in physical function, pain and stiffness, and the level of evidence is moderate. There is no difference between GE and HEP for most spinal mobility, but the level of evidence is low. The findings of studies assessing disease activity and cardiorespiratory fitness are conflicting.

Comparison 2.2: global postural re-education

Function, QoL, disease activity, pain and stiffness

Three studies compared group GPR to GE [21, 22, 33], and one study compared individual GPR with GE [23]. This latter study favoured individual GPR over GE in physical function, physical aspects of QoL, pain scores and morning stiffness duration, but the level of evidence is very low coming from this single level III study. There was no significant difference between-group GPR and GE programmes in physical function and disease activity outcomes, and the level of evidence is moderate from one level II study [33]. There was no difference in the effectiveness of group GPR and GE programmes in QoL, but the level of evidence was very low coming from one level III study [21].

Health-related fitness outcomes

There is very low evidence coming from one level III study [23] that individual GPR is superior to conventional GE in improving spinal mobility and CE. No significant between-group differences in spinal mobility or PFTs were reported; the level of evidence for no difference is moderate and very low, respectively [22, 33].

Comparison 2.3: aerobic exercise

Karapolat et al. [38] investigated the effects of adding aerobic exercise to a stretching and mobility HEP. The addition of swimming to a HEP significantly increased walking distance on 6MWT test compared to HEP alone, but no significant between-group differences were observed in cardiorespiratory variables. Niedermann et al. [29] found that the addition of aerobic training to a flexibility programme increased cardiorespiratory fitness measured with a submaximal bicycle test, but did not result in a significant difference in cardiovascular risk factors (cholesterol and triglycerides). There is no significant between-group differences in disease activity, quality of life or spinal mobility, and the level of evidence is moderate coming from two level II studies.

Comparison 2.4: multimodal exercise programmes

Roşu et al. [39] compared two multimodal HEP. A group performing a multimodal HEP of breathing, postural and stretching exercises (based on the Pilates, Heckscher and McKenzie methods) had significantly improved disease activity, physical function, spinal mobility and vital capacity compared to an exercise programme that combined step-aerobics and stretching. The risk of bias within this study is high, and the quality of evidence is low.

Comparison 3: therapeutic exercise compared to other modalities

Inpatient rehabilitation

Figen et al. [19] compared a 3-week HEP with 3 weeks of inpatient rehabilitation. Will et al. [18] compared high-frequency inpatient exercise with supervised outpatient exercise, both supplemented by HEP. Comprehensive inpatient rehabilitation did not significantly change physical function, disease activity or spinal mobility compared to outpatient exercise; the level of evidence of no difference between HEP and inpatient rehabilitation is moderate coming from two studies.

Balneotherapy

Altan et al. [24] compared the effect of balneotherapy and HEP to HEP alone. Disease activity and QoL were significantly improved in the balneotherapy and HEP groups immediately after intervention, but equivalent at 24-week follow-up. No significant group differences were found in physical function, pain, morning stiffness duration or spinal mobility. The level of evidence is moderate coming from one level II study.

Incentive spirometry

The addition of incentive spirometry exercises to a HEP did not significantly improve physical function (BASFI or 6MWT), disease activity, PFTs or spinal mobility compared to HEP alone [25]; the level of evidence of no difference is moderate coming from one level II study.

Spa-exercise

Van Tubergen et al. [13] compared the effects of two different, 3-week spa-exercise protocols (followed by 37 weeks of GE) with supervised GE. Data for the spa-exercise groups were pooled and compared to the supervised GE group. Pain and HAQ-S scores favoured the spa-exercise groups after the initial 3-week treatment at the spa centres. Pain remained significantly improved at 16 weeks, but this difference was no longer present 28 and 40 weeks into the intervention. The level of evidence from this single level II study is moderate.

Discussion

This review found evidence that therapeutic exercise has greater benefits than no intervention in improving physical function, disease activity, pain, stiffness, joint mobility and cardiovascular performance in adults with AS; evidence from trials examining QoL is conflicting. Exercise conducted under supervision has benefits over unsupervised HEP for QoL, but there is evidence of no difference, and conflicting evidence, across other outcomes. Spa-exercise and balneotherapy programmes have short-term benefits in QoL outcomes compared to GE; spa-exercise is also superior in pain relief, while balneotherapy further improves disease activity. Results from inpatient rehabilitation protocols were comparable to outpatient exercise protocols. These findings are in keeping with previous reviews [8, 40].

In comparisons of different exercise regimes, the addition of aerobic exercise to conventional stretching and mobility HEP results in superior functional fitness. Supplementing HEP with daily incentive spirometry does not yield additional benefits. Studies investigating different flexibility programmes have a high risk of bias; the GPR method delivered on an individual basis and a multimodal stretching and mobility programme appear superior to conventional exercise programmes.

The heterogeneity of exercise protocols and outcome measures employed preclude firm conclusions being drawn on the most effective exercise prescription. Vague descriptions of exercise protocols coupled with suboptimal dosage of exercise prescription, below that recommended to elicit physiological changes, add to the difficulty in assessing the impact of therapeutic exercise on SpA [41]. Furthermore, under-reporting of adherence to programmes was a feature of the included studies, making determining the efficacy of interventions problematic.

The outcome measures reported are principally self-report in nature, with few studies assessing physiological measures. The investigation of the effects of exercise interventions on health-related fitness has centred on flexibility and cardiorespiratory domains; the effect of exercise on muscular strength and endurance, and body composition has not been investigated. Despite the increase in cardiovascular morbidity and mortality among SpA populations, the potential benefits of therapeutic exercise programmes on cardiovascular risk factor are yet to be adequately investigated in SpA [9].

Most benefits observed immediately post-intervention were not maintained at follow-up. The chronic nature of SpA requires ongoing, regular exercise; however, the optimal frequency necessary to maintain benefits is unknown. In the last two decades, the emergence of biologics has dramatically changed pharmacological approaches to the management of SpA. With improved management of inflammatory symptoms, there has been decreased compliance with exercise [42]. Regular involvement in exercise also declines with increased disease duration [43]; long-term compliance with exercise, particularly in people with lower disability levels, presents a clinical challenge.

Study limitations and future research

Non-randomised controlled trials were included in this review to increase the scope of the review, but simultaneously increased the risk of bias. It is a further constraint that data extraction was performed by one reviewer. In practice, therapeutic exercise is frequently prescribed as part of a multimodal treatment plan [30, 44]; this review excluded studies examining exercise therapy in combination with other modalities as the relative effect of exercise therapy would be unknown. Combining exercise prescription with other modalities may yield different outcomes.

Participants in the included studies were almost exclusively diagnosed with AS; extrapolating findings to other SpA subtypes should be undertaken cautiously. Future studies should account for the evolving classification of SpA (e.g. predominantly axial SpA or predominantly peripheral SpA) and explore the effects of exercise on other SpA subtypes. Furthermore, comprehensive reporting of exercise protocols and participant adherence rates in studies is essential to understanding the effectiveness of exercise therapy. Targeted exercise prescription should meet the dosage recommended to achieve physiological changes. Methodological quality among studies in this review was mixed. Random sequence generation, adequate allocation concealment and blinding of outcome assessment in future RCTs would go some way towards addressing methodological shortcomings.

Conclusions

Current evidence shows therapeutic exercise to be beneficial for adults with AS, although the effects on other SpA subtypes are unknown. Expanding traditional programmes of flexibility exercises to include aerobic components may improve clinical outcomes, although the most effective exercise protocol remains unclear.

Conflict of interest The authors declare that they have no conflict of interest.

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