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Effects of high-intensity interval training on patients with inflammatory arthritis: a systematic review

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Abstract

Background Despite reports of clinical benefits, concerns persist about the stress associated with high-intensity interval training (HIIT) in patients with inflammatory arthritis (IA). This review aimed to assess the effects of HIIT on disease activity, immune function, symptoms, cardiorespiratory fitness (CRF), and overall health-related quality of life (HRQoL) in patients with IA.

Methods The PubMed, CINAHL, Cochrane Library, Web of Science, and Scopus databases were searched for eligible randomised controlled trials (RCTs). Data were extracted on the impacts of HIIT on IA conditions (i.e. rheumatoid arthritis (RA), psoriatic arthritis (PsA), and axial spondyloarthritis (axSpA)). Cochrane risk of bias tool 2.0 and PEDro scale were used in this review. This review was registered with PROSPERO (CRD42024577039).

Results Of 117 initial records, nine studies met the inclusion criteria, comprising 586 IA patients (HIIT = 285; controls = 301). Most studies ($n = 8$) reported stable disease activity, but one showed a slight decrease. Of four studies reporting pain/fatigue, pain scores remained unchanged in most studies ($n = 3$), except in one where there was a significant reduction in pain in the HIIT group ($p < 0.05$), and two studies reported a decrease in fatigue ($p < 0.05$). All studies evaluating CRF reported improvements, with one also indicating enhanced HRQoL. Body composition measures showed either reductions or no change, while imaging assessments in two studies revealed no significant differences.

Conclusion HIIT appears safe for patients with IA and does not exacerbate disease activity. HIIT resulted in improvement in CRF parameters, alongside positive changes in HRQoL. However, more high-quality RCTs are needed due to limited research in this area.

Keywords Cardiorespiratory fitness, Disease activity, Health status, Physical exercise, Rheumatoid arthritis

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Introduction

Inflammatory arthritis (IA) encompasses chronic autoimmune conditions characterised by systemic inflammation within entheses, bones, and the synovial membrane of joints [1]. This inflammatory process, marked by immune cell infiltration and heightened levels of pro-inflammatory cytokines, contributes to the degradation of cartilage and bone, and in certain instances, promotes new bone formations [2–4]. Consequently, IA presents with symptoms such as pain, stiffness, swelling, reduced mobility, and joint deformities [4–6]. IA conditions commonly include rheumatoid arthritis (RA), psoriatic arthritis (PsA), axial spondyloarthritis (axSpA), systemic lupus erythematosus, and gouts. The combined incidence of these IA conditions in the United Kingdom is estimated to be approximately 58 new cases per 100,000 people per year, with a prevalence ranging from 0.8 to 1.2% [7]. Among IA subtypes, RA is generally the most prevalent, while axSpA tends to be less common, though regional variations exist.

In managing IA, the European Alliance of Associations for Rheumatology (EULAR) recommends a combination of pharmacological and non-pharmacological interventions to help reduce inflammation, manage symptoms, preserve joint function, and improve the overall quality of life [8, 9]. Non-steroidal anti-inflammatory drugs (NSAIDs) and disease-modifying anti-rheumatic drugs (DMARDs) are first-choice pharmacological treatments in IA [10, 11]. Whilst effective in symptom relief and disease management, certain drugs are expensive and may lead to adverse effects such as gastrointestinal complications, heightened infection risk, and liver or kidney toxicity [12, 13]. Notably, non-pharmacological therapies are gaining momentum in supporting patients with IA. Growing evidence underscores the beneficial effects of physical activity (PA) and exercise in improving symptoms and reducing systemic inflammation associated with IA [14–16]. PA encompasses 'any bodily movement produced by skeletal muscles that requires energy expenditure. While PA refers to all movement including during leisure time, for transport to get to and from places, or as part of a person's work, exercise, a subset of PA, involves organised, structured, and repetitive movements intended to enhance or sustain physical fitness [17, 18]. Recent systematic reviews and meta-analyses examining the effects of exercise, including strength, aerobic, and flexibility training on IA have demonstrated positive outcomes [19–21]. These include improved disease activity, enhanced physical capacity, and better quality of life, with minimal safety concerns [19–21]. Furthermore, exercise interventions have demonstrated the suppression of inflammatory cytokine expression, thereby aiding in reduced joint destruction in IA [22].

According to current EULAR recommendations, individuals with IA are advised to engage in 150 min of moderate-intensity PA or 75 min of vigorous activity per week, supplemented by strength and flexibility exercise twice weekly [9]. However, disease-specific barriers, such as limited understanding of the condition, uncertainties regarding safe exercise practices, and the presence of symptoms like pain, fatigue, and reduced mobility, often contribute to low adherence to PA among individuals with IA [9]. Consequently, a significant majority fail to meet the recommended PA guidelines [23, 24]. Low levels of PA have been associated with reducing cardiorespiratory fitness (CRF) in individuals with IA [25, 26]. Furthermore, studies indicate that individuals with IA face an increased probability of cardiovascular disease (CVD), potentially linked to chronic systemic inflammation and sedentary lifestyles [27, 28]. Thus, this population experiences elevated mortality rates in contrast to the general populace, with more than half of early deaths attributed to CVD [29].

Cardiorespiratory fitness, typically assessed by maximal oxygen uptake (VO_2max), is a vital gauge of overall health [30]. Engaging in aerobic exercise can improve VO_2max, thereby enhancing physical capacity and performance, while also reducing the risk of CVD and all-cause mortality [31]. Furthermore, aerobic training has shown promise in reducing symptom burden and inflammation among individuals with IA [32, 33]. As symptoms and function improve, the inclination towards general PA may increase, thereby lowering barriers to engagement [34, 35].

Aerobic exercise encompassing activities like jogging, walking, and cycling, can be structured based on volume, frequency, and notably intensity, which is crucial for improvements in VO_2max [36, 37]. High-intensity training has proven better than moderate or low-intensity training in increasing CRF [37, 38]. A typical protocol for organising aerobic high-intensity interval training (HIIT) involves four sets of four-minute work bouts performed at 85-95% of maximal heart rate (HRmax), combined with periods of active recovery lasting three minutes at around 70% HRmax [39]. This model has consistently demonstrated effective increases in VO_2max across diverse demographics, including healthy individuals, as well as various patient groups [40–42]. Furthermore, HIIT has demonstrated safety and effectiveness amongst patients with IA, leading to comparable improvements in VO_2max as observed in healthy populations [32, 43, 44]. Recent research has demonstrated that HIIT is not only successful in enhancing CRF but also in improving disease activity, enhancing skeletal muscle remodeling and innate immune cell function, as well as promoting physical function and health-related quality of life among patients with IA [32, 43–48]. Moreover, a

qualitative study by Bilberg et al. explored the experiences of patients with axSpA following a 12-week HIIT programme [49]. The participants reported enhanced physical fitness, energy, and overall health, along with improved mood and greater enjoyment compared to conventional exercise. They also described a positive sense of embodiment, increased awareness of their physical capabilities, and greater confidence in their bodies, which contributed to a shift in their perception of the disease. Additionally, physiotherapists' guidance and encouragement were instrumental in boosting patients' self-efficacy toward high-intensity exercise [49]. However, there remains a degree of ambivalence among physiotherapists and healthcare professionals regarding high-intensity exercise due to concerns about potential adverse effects on disease activity and joint health [50, 51]. This concern stems from the notion of mechanical stress as a contributing factor to disease onset and advancement [52]. It is postulated that high-intensity exercise may increase biomechanical stress and micro damage at affected sites, potentially exacerbating inflammation and consequently worsening disease outcomes [52, 53]. Given the concerns surrounding high-intensity exercise, it is essential to further investigate this area to inform optimal and individualised recommendations. A clear gap in the literature exists, as no systematic review to date has examined the effects of HIIT in individuals with IA. This systematic review aimed to evaluate the existing evidence base regarding the effects of HIIT on disease activity, immune function, symptoms, CRF, and overall health status in patients with IA. This systematic review aimed to assess the current evidence on the effects of HIIT on disease activity, immune function, symptoms, CRF, and overall health status in patients with IA.

Methods

This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines [54]. This review is registered at https://www.crd.york.ac.uk/PROSPERO - CRD42024577039. Article searches were conducted on selected electronic databases - PUBMED, CINAHL, Cochrane Library, Web of Science, and Scopus from inception to March 16, 2025. The Population, Intervention, Comparison, Outcomes, and Study (PICOS) framework guided article selection and search strategy development [55]. Subsequently, keywords related to disease type (e.g., IA) and intervention (e.g., HIIT) were identified from titles and abstracts, then combined using Boolean operators ('AND', 'OR').Additionally, a Medical Subject Heading (MeSH) system was utilised for enhanced search. The search strategy for each database is presented in the Supplementary Table 1.

Eligibility criteria

Randomised controlled trials (RCTs) were prioritised for their methodological rigour and relevance to the research question [56]. Studies were included if they involved adults (≥ 18 years) diagnosed with IA, specifically RA, PsA, or axSpA, and employed aerobic HIIT protocols (≥ 80% HRmax) with active recovery, alone or alongside other therapies. Due to variability in control conditions, standardisation across control groups was not feasible. The primary outcome was disease activity, a key metric for both patients and clinicians in guiding treatment and predicting outcomes such as severity and hospitalisation [57]. Secondary outcomes included inflammatory markers, immune function, symptoms (pain and fatigue), CRF, functional ability, and overall health status.

Study selection

Following database retrieval, two researchers (CS and TG) assessed potential studies, removing duplicates and screening titles and abstracts to determine eligibility. A third reviewer (CM) arbitrated any conflict in the article screening.

Relevant citations were imported into EndNote (Version 21) and de-duplicated. Remaining articles were screened by title, abstract, and full text against predefined eligibility criteria, including language, study type, participant characteristics, intervention, and outcomes. Reference lists of included studies were also manually reviewed to identify additional relevant articles.

Data collection

Data extraction was performed using the Systematic Review Data Repository (SRDR) [58]. For each eligible study, full texts were reviewed and data were extracted on study characteristics, including author, year, setting, country, design, sample size, and intervention comparisons. Additionally, population characteristics such as participant number, mean age, gender, IA subtype, disease activity, and duration were extracted. Intervention details such as exercise type, session frequency, duration, and assessment time points were recorded. Key outcomes included disease activity, immune and inflammatory markers, symptoms, functional ability, health status, and CRF. All data were organised into tables and described narratively.

Risk of bias assessment

The methodological quality of eligible RCTs was assessed using the Cochrane Risk of Bias Tool 2 (RoB2), which evaluates six domains: selection, performance, detection, attrition, and reporting bias [59]. Each study was classified as having low risk, some concerns, or high risk of bias. Additionally, the quality of selected RCTs was also assessed using the PEDro scale, which evaluates

10 criteria including randomisation, blinding, and follow-up [60]. With excellent inter-rater reliability (ICC 0.80–0.89), the scale assigns scores indicating methodological quality: 0–3 (poor), 4–5 (fair), 6–8 (good), and 9–10 (excellent) [61].

Summary measures and data synthesis

Studies were categorised by design and outcome measures. When possible, mean differences (MD) and 95% confidence intervals (CI) for between-group changes were calculated using Review Manager (Version 5.4); otherwise, original reported results were used. Clinical heterogeneity was assessed based on participant characteristics, interventions, and outcomes. Due to substantial clinical and methodological diversity, meta-analysis was not feasible, and a narrative synthesis was conducted instead.

Results

Study selection

The initial search across five databases yielded 117 records (PUBMED: 14, Web of Science: 27, CINAHL: 9, Cochrane Library: 25, Scopus: 42). After de-duplication, 75 records remained. Title, abstract, and full-text screening identified 8 eligible studies. One additional study was found through reference list screening, resulting in 9 included RCTs. The PRISMA flowchart showing the selection process is presented in Fig. 1.

Study characteristics

As shown in Table 1, the nine studies included in this review, which were published between 1993 and March 2025, involved a total of 586 patients. There has been a notable increase in publications since 2018. All studies were published in English and were conducted in Norway ($n=7$), Denmark ($n=1$), and Sweden ($n=1$). The studies took place in various settings, including hospitals, clinics, research laboratories, and home environments. The average age of participants was 50.7 years, and their disease activity was generally low to moderate. The interventions lasted between 8 and 12 weeks, with participants undergoing 2 to 5 sessions per week, utilising HIIT modalities such as cycling, treadmill walking or running, and uphill walking. Outcomes were evaluated before and after the intervention and included measures of disease activity, immune markers, symptoms, CRF, health status, body composition, and imaging results.

Risk of bias assessment

The results of the ROB2 assessment for the included RCTs are depicted in Fig. 2. While the majority of RCTs exhibited some concerns, one study was identified as having a high risk of bias [62]. Notably, the three articles authored by Thomsen et al. and the article by Chronaiou et al. reported on the same trial but were considered separately as they evaluated different outcome measures [62–65]. Eight studies reported adequate methods for randomisation and allocation concealment. However, Baslund et al. did not provide information on allocation concealment [66]. Additionally, although this study targeted RA patients, one patient in the control group was diagnosed with PsA after study enrolment, yet was not excluded from the analysis. All studies exhibited some concerns regarding deviations from the intended

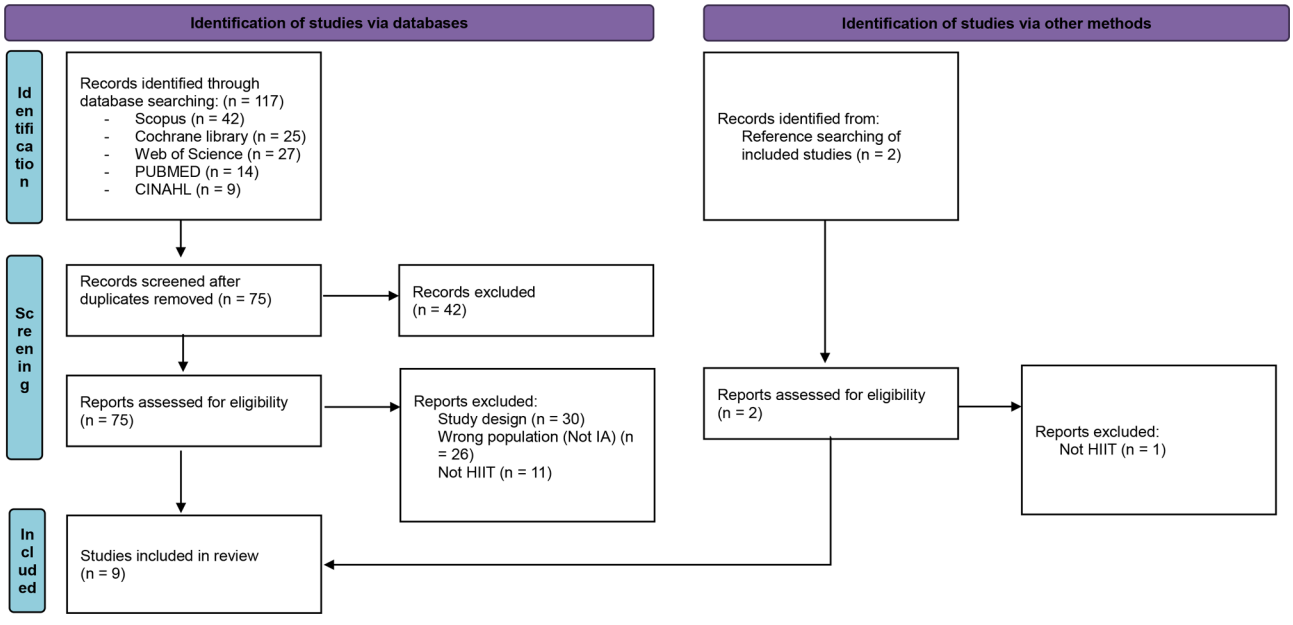

Fig. 1 PRISMA flow diagramdepicting the study selection process for the systematic review

Table 1 Key characteristics of the included studies

Study characteristics	Population characteristics	Intervention	Outcome measures
Author: Baslundet al. [62] Year: 1993 Setting: Not included Country: Denmark Design: RCT Sample size: no calculation prior Comparator: Controls were not trained	Number: 9 (HIIT group) Age mean(SD): 49(3) Yrs Gender: 8 female / 1 male IA condition: RA Disease activity level: Moderate Disease duration mean(SD): 16(4) Yrs	Type: Bicycle ergometer Number of sessions: 4 to 5 x per week Duration: 8 weeks Protocol: 3 × 5 min at fixed target HR (averaging 85–95% HRmax). 5 min active recovery in between.	Ax time points: baseline, halfway and post. Key outcomes: Immune parameters (Blood sample) VO_2max HR RPE Workload
Author: Thomsen et al. [63] Year: 2018 (from 2013–2015) Setting: Hospital and research laboratory Country: Norway Design: RCT Sample size: 30 patients needed for each group Comparator: No change in pre-study PA habits	Number: 30 (HIIT group) Age mean(SD): 50.5(11.1) Yrs Gender: Female- 21 (70%) IA condition: PsA Disease activity level: low to moderate Disease duration mean(range): 6(2–12) Yrs	Type: Stationary bike Number of sessions: x3 per week Duration: 11 weeks Protocol: HIIT 4 × 4 min (85-95% HRmax). 3 min 70% - Supervised: x2 per week. Unsupervised: x1 per week.	Ax time points: Baseline, 3- and 9-months follow-up. Key outcomes: VO2max Body composition Resting HR
Author: Thomsen et al. [64] Year: 2019 (from 2013 to 2015) Setting: Hospital and research laboratory Country: Norway Design: RCT Sample size: 30 patients needed for each group Comparator: No change in pre-study PA habits	Number: 32 (HIIT group) Age mean(SD): 50.7(11) Yrs Gender: Female- 21 (66%) IA condition: PsA Disease activity level: low to moderate Disease duration mean(range): 5.5 (2–12) Yrs	Type: Stationary bike Number of sessions: x3 per week Duration: 11 weeks Protocol: HIIT 4 × 4 min (85-95% HRmax). 3 min 70%. Supervised: x2 per week. Unsupervised: x1 per week.	Ax time points: Baseline, 3- and 9-months follow-up. Key outcomes: PGA Fatigue Pain DAS44 ASDAS-CRP SPARCC
Author: Sveaaset al. [32] Year: 2020 (from 2015 to 2016) Setting: Hospital Country: Norway Design: RCT Sample size: 100 patients needed Comparator: Usual care	Number: 50 (HIIT group) Age mean(SD): 46.2 (23–69) Yrs Gender: 53 females. 47 males. IA condition: axSpA Disease activity level: moderate to high Disease duration: Not provided	Type: Not stated Number of sessions: x3 per week Duration: 12 weeks Protocol: ACSM guidelines (HIIT 4 × 4 min (85-95% HRmax). 3 min 70%). Supervised: x2 per week. Unsupervised: x1 per	Ax time points: Baseline and after 12 weeks Key outcomes: ASDAS BASDAI BASFI BASMI VO2peak ESR BMI Weight Waist circumference DXA
Author: Chronaiouet al. [65] Year: 2022 (from 2013 to 2015) Setting: Hospital and research laboratory Country: Norway Design: RCT Sample size: No calculation Comparator: No changes from pre-study PA habits	Number: 19 (HIIT group) Age mean(SD): 52 (39–64) Yrs Gender: 15 females. 4 males. IA condition: PsA Disease activity level: low to moderate Disease duration: Not provided.	Type: Stationary bike Number of sessions: x3 per week Duration: 11 weeks Protocol: HIIT 4 × 4 min (85-95% HRmax). 3 min 70%. Supervised: x2 per week. Unsupervised: x1 per week.	Ax time points: Baseline and after 11 weeks Key outcomes: Disease activity- PGA HS-CRP BASDAI DAS44 MRI Spine - BMO SPARCC Extraction of textual features
Author: Thomsen et al. [66] Year: 2023 Setting: Hospital and research laboratory Country: Norway Design: RCT Sample size: 30 patients needed Comparator: No change in pre-study PA habits	Number: 32 (HIIT group) Age mean(SD): 50.7(11.0) Yrs Gender: 21 female. 11 male. IA condition: PsA Disease activity level: low to moderate Disease duration mean(range): 5.5(2–12) Yrs	Type: Stationary bike Number of sessions: x3 per week Duration: 11 weeks Protocol: HIIT 4 × 4 min (85-95% HRmax). 3 min 70%. Supervised: x2 per week. Unsupervised: x1 per week.	Ax time points: Baseline and 3 months Key outcomes: US (joints and enthese) MRI of the SIJ and spine SPARCC scoring

Table 1 (continued)

Study characteristics	Population characteristics	Intervention	Outcome measures
Author: Hagloet al. [44] Year: 2021 Setting: clinical setting and home-based setting Country: Norway Design: RCT Sample size: 16 patients in each group needed. Comparator: SG HIIT / AG HIIT	Number: AG HIIT 19 / SG HIIT 21 Age mean(SD): AG 48(12) Yrs / SG 50(11) yrs Gender: AG 14 female 5 male / SG 19 female 5 male IA condition: RA, SPA and SLE Disease activity level: not included Disease duration mean(SD): AG 13(9) Yrs / SG 10(9) Yrs	Type: Treadmill or outdoor uphill walking Number of sessions: x2 per week. Duration: 10 weeks Protocol: 2 groups. AG HIIT or SG HIIT. 4×4 min 85-95% HRmax, 3 min 70% HRmax.	Ax time points: pre- and post-intervention. Key outcomes: VO2max HRmax Oxygen pulse Pulmonary ventilation Respiratory exchange ratio Body composition HRQOL - RAND-36
Author: Norden et al. [67] Year: 2024 (from 2021–2023) Setting: Primary care Country: Norway Design: RCT Sample size: 60 patients needed Comparator: Usual care	Number: 30 (HIIT group) Age mean(SD): 60 (51–63) Gender: 17 females, 13 males IA condition: RA, SpA or PsA Disease activity level: remission to high.Disease duration mean(range): 13 (6–31) Yrs.	Type: Uphill walking or running (or cycling, rowing, X trainer) Number of sessions: x3 per week Duration: 12 weeks Protocol: x2 supervised HIIT. 4×4 min 90–95% HR peak. 2–3 min 60–70% HR peak. x1 unsupervised at 70% HR peak.	Ax time points: baseline, 3 month and 6 months. Key outcomes: VO_2peak Body composition Inflammatory markers DAS-28, ASDAS and disease activity index for PsA BP and resting HR Lipids NRS pain and fatigue Physical activity index Exercise beliefs and self-efficacy
Author: Bilberget al. [68] Year: 2024(from 2021–2023) Setting: Hospital Country: Sweden Design: RCT Sample size: 87 patients needed Comparator: Usual care	Number: 43 (HIIT group) Age mean(SD): 48.2 (9.7) Gender: 73 females 14 males IA condition: RA Disease activity level: Low to moderate Disease duration mean(range): > 1 Yr.	Type: Stationary bike Number of sessions: x3 per week Duration: 12 weeks Protocol: x2 supervised HIIT. 4×4 min 90–95% HR peak. 3 min 60–70% HR peak. x1 unsupervised at 70% HR peak.	Ax time points: baseline and 3 months. Key outcomes: VO_2max, VO_2, ventilatory maximum, oxygen pulse, Resting blood pressure , 1-minute sit-to-stand, Isometric handgrip strength, Anthropometry, Lipid status, Disease Activity Score (DAS28), Physical activity, Pain (VAS) and overall health (VAS Global), Changes in symptoms (PGIC)

AG: App-based group; ASDAS-CRP: Ankylosing Spondylitis Disease Activity Score using the CRP level; Ax: assessment; BASDAI: Bath Ankylosing Spondylitis Disease Activity Index; BMI: body mass index; BMO: bone marrow oedema; BP: blood pressure; CI: confidence interval; CRP: c-reactive protein; DAS-28: Disease Activity Score in 28 joints; DAS44: disease activity score of 44 joints; ESR: erythrocyte sedimentation rate; HAQ-DI: health assessment questionnaire-disability index; HIIT: high-intensity interval training; HR: heart rate; HRQOL: health related quality of life; HRR: heart rate reserve; IA: inflammatory arthritis; kg: kilograms; min: minute; MRI: magnetic resonance imaging; NRS: numerical rating scale; PA: physical activity; PGA: patient's global assessment; RA: rheumatoid arthritis; RCT: randomised controlled trial; RPE: rating or perceived exhaustion; RAND-36: Norwegian version of Short-Form Health Survey; SD: standard deviation; SIJ: sacroiliac joints: seconds; SG: supervised group; SPARCC: Spondylarthritis Research Consortium of Canada; SPA: spondylarthritis, SLE: systemic lupus erythematosus; US: ultrasound; VO2max: Maximal oxygen consumption, ACSM: American College of Sports Medicine; PGIC: Patient Global Impression of Change; BASFI: Bath Ankylosing Spondylitis Functional Index; BASMI: Bath Ankylosing Spondylitis Metrology Index; DXA: dual-energy X-ray absorptiometry; Yrs: years

interventions, with patients and professionals delivering the intervention being aware of the assigned groups in all cases. Five studies did not provide information on whether deviations from the intended intervention occurred due to contextual factors. Moreover, three studies did not conduct an intention-to-treat (ITT) analysis. Two studies raised concerns regarding missing outcome data. Specifically, in the study by Chronaiou et al., data was only available for 79% of randomised patients due to deviations in the MRI protocol [64]. In the study by Thomsen et al., data was available for 85% of patients, but limited information was provided regarding reasons for dropout [65]. Considering outcome measurement, Baslund et al. did not report information on the blinding of assessors [66]. Furthermore, Thomsen et al. were deemed to have a high risk of bias due to lack of blinding of the assessor, potentially influencing the Patient's Global Assessment (PGA) score based on knowledge of the intervention received [62]. Thomsen et al. raised some concerns because the rheumatologist evaluating ultrasound (US) was not blinded to the groups, posing a risk for diagnostic detection bias, although this did not seem to impact the study results [65]. All studies were rated as low risk of bias for the selection of the reported results.

Table 2 summarises the methodological quality scores assessed using the PEDro scale. Scores ranged from five to eight across the studies. Notably, eight studies achieved a classification of "good," indicating robust methodological quality, while the study conducted by Baslund et al., was rated as "fair" [66].

Synthesis of results

Disease activity and immune function

Baslund et al. found no differences in immune parameters between HIIT and control groups in RA patients

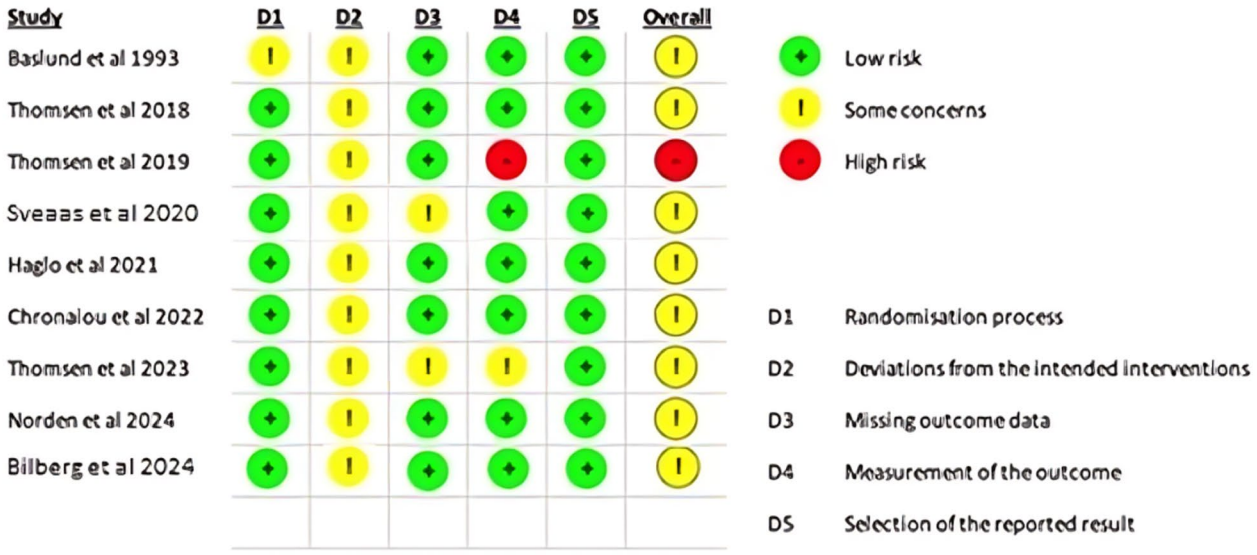

Fig. 2 Assessment of included RCTs' risk of bias using ROB2

[66]. Similarly, Thomsen et al. observed no group differences in PsA disease activity at three and nine months post-HIIT [62]. Additionally, Norden et al. found no group differences in disease activity across RA, PsA, and axSpA patients following HIIT at three- and six-month follow-ups [67]. Similarly, Bilberg et al. observed no group difference in RA disease activity at 3-month follow-up [68]. In addition, Sveaas et al. observed a significant reduction in disease activity among patients with axSpA between HIIT and usual care (ASDAS: −0.6 [−0.8 to −0.3], $p < 0.001$ and BASDAI: −1.2 [−1.8 to −0.7], $p < 0.001$) in favour of HIIT [32].

Symptoms

Sveaas et al. reported a significant reduction in pain (BASDAI-neck/back/hip pain: −1.7 (−2.4 to 0.9), $p < 0.001$; BASDAI-peripheral pain: −1.0 (−1.9 to 0.2), $p = 0.016$)) and fatigue (BASDAI-fatigue: −1.4 (−2.2 to 0.6), $p < 0.001$) in HIIT group at 3 months [32]. Thomsen et al. found no difference in pain intensity between groups but reported reduced fatigue levels in the HIIT group at three months (−12.83 mm [95% CI −25.88, 0.23]); however, this effect did not persist at the nine-month follow-up [62]. Furthermore, Bilberg et al. found no group difference in pain intensity at 3 months follow-up [68]. Likewise, Norden et al. detected no difference in pain and fatigue between intervention and control groups across the follow-up periods [67].

Cardiorespiratory fitness

In Baslund et al., HIIT resulted in a significant 22% increase in VO_2max ($P = 0.04$), marking a notable difference from the control group [66]. Similarly, Thomsen et al. observed higher VO_2max levels in the HIIT group, with a 3.72 mL/kg/min (95% CI 2.38 to 5.06) increase compared to controls at three months, maintaining a 3.08 mL/kg/min (95% CI 1.63 to 4.53) difference at nine months [63]. Haglo et al. reported increased VO_2max in both HIIT groups, with a 10% (SD 4%) increase in the app-based group (AG) and a 12% (SD 4%) increase in the supervised group (SG), with no significant difference between groups [44]. Norden et al. noted a 2.5 mL/kg/min (95% CI 0.9 to 4.0) greater change in VO_2peak in the exercise group compared to controls at three months, a difference sustained at six months with a mean change of 2.6 mL/kg/min (95% CI 0.8 to 4.3) [67]. Sveaas et al. reported an 8.2% significant increase in VO2 peak among patients in the HIIT group at 3-month follow-up [32]. Furthermore, Bilberg et al. observed a significant mean group difference in VO_2max (3.71 mL/kg/min; 95% CI 2.16, 5.25) at 3 months in favour of the HIIT group [68].

Health status

Chronaiou et al. found no change in Patient's Global Assessment (PGA) scores post-intervention, with no difference between HIIT and control groups [64]. Haglo et al. demonstrated improvements in multiple dimensions of HRQoL across both HIIT groups: bodily pain decreased significantly by 11.3 (SD 17.4; $P = 0.04$) in AG and 16.7 (SD 12.6; $P < 0.001$) in SG; vitality improved by 10.4 (SD 13.1; $P = 0.01$) in AG and 16.9 (SD 17.8; $P = 0.001$) in SG; social functioning increased by 10.7 (SD 18.3; $P = 0.04$) in AG and 18.5 (SD 15.1; $P < 0.001$) in SG, with no differences between groups post-training [44]. Moreover, improvements in general health (8.8; SD 10.5; $P = 0.003$), physical functioning (7.4; SD 9.7; $P = 0.004$),

Table 2 Assessment of methodological quality using the PEDro scale for RCTs

Author (year)	Eligibility specified	Randomised groups	Concealed allocation	Baseline characteristics similar between groups	Blinding of subjects	Blinding of therapists	Blinding of outcome assessors	Low loss to follow-up	Intention to treat analyses	Reported between-group statistical comparisons	Report point measures and variability measures	Total score (/10)
Baslund [62]	Y	Y	N	Y	N	N	N	Y	Y	Y	N	**5**
Thomsen [63]	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	**8**
Thomsen [65]	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	**7**
Sveaas [32]	Y	Y	Y	Y	N	N	Y	Y	N	Y	Y	**7**
Haglo [44]	Y	Y	Y	Y	N	N	Y	Y	N	Y	Y	**7**
Chronaiou [65]	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	**7**
Thomsen [66]	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	**7**
Norden [67]	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	**8**
Bilberg [68]	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	**8**
Percentage of studies meeting each criterion	**100%**	**100%**	**88.9%**	**100%**	**0%**	**0%**	**66.7%**	**88.9%**	**77.8%**	**100%**	**88.9%**	

N: no; PEDro: Physiotherapy Evidence Database; Y: yes; a Item one ('eligibility criteria') is not included in the PEDro total score

and emotional well-being (7.2; SD 6.9; $P = 0.001$) were noted in SG, with no significant differences between groups post-training [44].Finally, Bilberg et al. observed a significant difference in overall health status (– 14.7; 95% CI – 23.8 to – 5.50) at 3 months in favour of HIIT [68].

Body composition

In the Thomsen et al. study, at three months, the HIIT group showed a 1.28% lower truncal fat mass (95% CI – 2.51 to – 0.05) compared to controls [63]. Additionally, there were indications of slightly lower total fat percentage (– 0.80; 95% CI – 1.71 to 0.10) and BMI (– 0.31; 95% CI – 0.78 to 0.17) in the HIIT group compared to controls, but no difference in lean muscle mass was observed. However, at the nine-month mark, no differences in anthropometric measures were found between the two groups [63]. Similarly, Norden et al. found no group differences in anthropometric parameters at various follow-up time points [67]. Sveaas et al. observed a significant reduction in waist circumference (– 1.7 (– 3.2 to 0.2); $p = 0.031$) in the HIIT group compared to usual care [32]. Furthermore, at 3 months, Bilberg et al. found a significant decrease in waist circumference in HIIT (– 2.6; 95% CI – 5.09 to – 0.18) [68]. However, Sveaas et al. and Bilberg et al. reported no significant differences in BMI and weight between the groups [32, 68].

Imaging

Sveaas et al. assessed muscle mass with a whole-body dual-energy X-ray absorptiometry and found no significant difference in the effects of HIIT on lean mass (998 g [– 50 to 2025], $p = 0.061$) [32]. Chronaiou et al. investigated the effects of HIIT on the axial skeleton in PsA patients using MR images of the spine for bone marrow oedema (BMO) and textural features. However, no differences were found between HIIT and control groups about changes in BMO or Spondyloarthritis Research Consortium of Canada (SPARCC) scores after 11 weeks [64]. Similarly, there were no differences in changes to textural features of PsA lesions between groups [64]. Thomsen et al. examined HIIT's impact on inflammation in PsA, using ultrasound (US) to assess peripheral joints and entheses, and MRI for BMO in sacroiliac joints (SIJ) and spine. The study found no clear indication of increased inflammation risk after HIIT compared to controls [65].

Discussion

This review evaluated the effectiveness of HIIT in reducing disease activity and improving outcomes such as immune function, symptoms, CRF, and overall health in patients with IA. The majority of studies reviewed reported either no significant change or a reduction in disease activity following HIIT [32, 62, 66–68]. Sveaas

et al. reported a decrease in disease activity in the HIIT group [32]. Also, four studies found no significant difference in disease activity and/or immune parameters between the HIIT groups and the control group [62, 66–68]. Contrary to initial hypotheses, high-intensity exercise in patients with IA did not exacerbate disease activity, as observed across the included studies [53]. Studies have shown that HIIT can significantly improve overall physical health, but its impact on disease activity in IA patients is often minimal [9, 69]. Another study by Bartlett et al. found that HIIT significantly leads to substantial changes in disease activity [48].

Interestingly, prior research has reported a slight reduction in disease activity following exercise [70]. This current review's findings suggest that the lack of decrease in most of the included studies may be explained by the predominance of patients with low baseline levels of inflammatory markers, potentially resulting in a floor effect and limiting the magnitude of change [67]. Moreover, Andonian et al. revealed a distinct phenotype associated with exercise-induced anti-inflammatory responses in established RA through analysis of two cohorts (cross-sectional and pre/post-HIIT) [46]. This phenotype, characterised by older age, heightened inflammation, lower aerobic fitness, and metabolic pathway alterations in skeletal muscle, reveals the complex interplay between exercise, systemic immune responses, and skeletal muscle metabolism [46]. Transcriptomic analyses highlighted significant gene expression modifications in pathways related to amino acid catabolism, glycolysis regulation, and tricarboxylic acid cycle flux within the skeletal muscle of sedentary RA patients [46]. These findings suggest a potential link between the transcriptional profile of RA-afflicted muscles and HIIT-mediated decreases in disease activity, implying that exercise-induced inflammation alteration may coincide with the reprogramming of skeletal muscle metabolism [46].

Four RCTs evaluated symptoms, primarily focusing on pain intensity and fatigue [32, 62, 67, 68]. Pain intensity remained unchanged in most studies, except in Sveaas et al. where a significant decrease in pain and fatigue at 3-month follow-up was reported [32]. Bilberg et al. and Norden et al. reported no significant difference in pain or fatigue at follow-up time points [67, 68]. Similarly, Thomsen et al. found no difference in pain intensity but noted lower fatigue levels at three months, although not sustained at nine months [62]. Fatigue, a prevalent issue in IA, remains poorly understood, potentially linked to inflammation, and has been correlated with higher disease activity [71, 72]. In IA patients, increased fatigue often corresponds with heightened pain [73]. However, the included studies did not observe a significant impact on pain intensity alongside reduced fatigue. Notably, most patients had mild to moderate baseline pain, possibly limiting the potential for pain reduction. Another explanation for reduced fatigue could stem from exercise-induced endorphin release or enhanced aerobic capacity [74, 75]. Consequently, the diminished effect on fatigue in the HIIT group at nine months may result from less than 50% of the patients in the HIIT group maintaining exercise, with those continuing potentially exercising at reduced intensity [62]. Cuenca-Martínez et al. in a systematic review and meta-analysis highlighted that HIIT effectively reduces pain intensity, but does not significantly impact disability [69]. In addition, HIIT exercise in patients with IA led to a temporary reduction in fatigue [32, 62]. Similarly, Bartlett et al. highlighted that HIIT is associated with reduced disease activity and can help alleviate fatigue [48].

Six RCTs assessed VO_2max (or VO_2peak), all demonstrating significant increases post-HIIT compared to control groups [32, 44, 63, 66–68]. This improvement was sustained at three months in Bilberg et al. and Sveaas et al., six months in Norden et al., and at nine months in Thomsen et al. [32, 63, 67, 68]. Additionally, Baslund et al. reported decreased HR and rating of perceived exertion (RPE), while Haglo et al. and Bilberg et al. observed increases in oxygen pulse and ventilation [44, 66, 68]. Norden et al. documented enhanced VO_2peak measured in absolute capacity, relative to fat-free mass (FFM), and oxygen pulse at both three- and six-month follow-ups, with no significant differences in resting HR, BP, or blood biochemistry [67]. Patients with IA are predisposed to CVD and exhibit an increased incidence of CVD risk factors, underscoring the importance of mitigating these risks alongside disease-modifying treatments [27, 28, 63]. The effect on VO_2max aligns with prior studies of HIIT in healthy individuals and patient cohorts, surpassing the threshold associated with a decrease in overall mortality [37, 76–78]. Norden et al. and Thomsen et al. demonstrated a lasting effect on VO2max at six and nine months, respectively, suggesting sustained improvements in cardiorespiratory fitness with reduced training efforts over time [63, 67]. In Norden et al., despite over 80% of individuals presenting an elevated CVD risk, many were taking anti-hypertensives and/or statins, and baseline BP and lipid levels met recommended targets, potentially limiting further adaptation to exercise [67].

In this review, all studies assessing CRF observed increased aerobic capacity and positive changes were observed in HRQoL. Body composition measures showed no significant differences or slight decreases. Imaging investigations revealed no changes across the studies. Haglo et al. reported increased HRQoL in both app-based and supervised groups post-intervention, particularly in bodily pain, vitality, and social functioning [44]. Moreover, the supervised group exhibited improvements in general health, physical functioning,

and emotional well-being [44]. These enhancements suggest a potential reduction in symptom burden among IA patients [79]. Furthermore, Bilberg et al. observed better overall health status with HIIT using VAS-global [68]. However, both Chronaiou et al. and Thomsen et al. discovered no significant changes in the patient's global assessment [62, 64].

Thomsen et al. noted a decrease in truncal fat mass and a slight reduction in total fat percentage and BMI compared to the control group post-intervention, although no differences were seen in lean muscle mass [63]. However, at the nine-month mark, there were no differences in anthropometric measures. Similarly, Bilberg et al. and Sveaas et al. found a significant decrease in waist circumference at 3-month follow-up in HIIT compared to usual care [32, 68]. This reduction in fat percentage following HIIT aligns with previous research indicating a notable impact on body composition, characterised by reduced total body fat and heightened fatty acid oxidation [77, 80]. Of relevance, abdominal fat, particularly visceral fat, plays a crucial role in metabolic syndrome and is closely linked to CVD risk [81, 82]. Adipose tissue functions as an endocrine organ, creating inflammatory mediators that significantly affect the pathophysiology of both CVD and inflammatory diseases [83]. In contrast, Norden et al. found no significant differences in this regard [67].

Chronaiou et al. found no differences between the HIIT and control groups regarding changes in bone marrow oedema, Spondylarthritis Research Consortium of Canada scores, or textural features [64]. Similarly, Thomsen et al. did not identify clear evidence of elevated inflammation, as assessed by ultrasound of peripheral joints and entheses, or bone marrow oedema on magnetic resonance imaging of the sacroiliac joint and spine [65]. These findings diverge from the hypothesis positing that mechanical stress in an inflammatory environment might precipitate the onset of enthesitis [84]. One plausible explanation could be the low disease activity at baseline owing to effective medical management, potentially shielding the patients from experiencing a flare-up following the HIIT intervention [65]. Moreover, the HIIT regimen, conducted on a stationary bicycle, likely minimised mechanical stress on the lower limbs and back [65].

Limitations of the findings

The risk of bias across the included studies was moderate, with Thomsen et al. deemed to have a high risk [62]. Notably, four of the included studies reported on the same trial [62–65]. Moreover, individuals who volunteer for trials involving physical exercise may inherently possess greater experience with and motivation for PA and exercise, thereby potentially limiting the generalisability of the results. The relatively small sample sizes of the included studies may have diminished the precision of the estimated effects. The lack of power calculation of the outcomes of interest in the secondary analysis three articles of Thomsen et al. and Chronaiou et al. might have led to insufficient power to detect true changes in the outcomes [62–65]. Additionally, the duration of the studies, ranging from eight to 12 weeks, was relatively short. A longer intervention duration might be expected to yield clinically relevant effects across a broader array of outcomes. Furthermore, it is conceivable that the effects observed in the intervention group could, in part, be attributed to a broader shift toward healthier lifestyle behaviours, encompassing diet, nutrition, and overall physical activity. The absence of blinding in outcome assessment within some of the studies raises the possibility of bias influencing the results. Furthermore, certain patient-reported outcome measures may prove challenging to interpret, as factors beyond disease activity—such as permanent damage, psychological distress, and comorbidities—could impact reporting. Lastly, it's worth noting that HIIT represents a form of exercise that may present challenges when performed without ongoing guidance or supervision over time.

These limitations encompass various aspects, including the potential for bias and subjectivity in study selection and data extraction, and limited expertise and perspectives which may affect the comprehensiveness and accuracy of the review [85]. Furthermore, the absence of validation and quality assurance mechanisms, as well as the limited capacity for handling heterogeneity in the included studies, pose additional challenges to the reliability and validity of the review's findings [86]. Despite these constraints, the systematic review aims to provide valuable insights into the research question at hand. Collaborative efforts involving multiple researchers with diverse expertise are essential for mitigating these limitations and ensuring the quality and reliability of systematic reviews in general [87].

Implications and future research

The findings of this review indicate that HIIT appears to be safe and does not exacerbate disease activity in IA patients. Additionally, HIIT elicits comparable increases in CRF to those observed in healthy individuals, presenting a promising intervention for addressing low CRF, CVD, and associated risk factors. However, the review highlights the limited research in this area, emphasising the need for more high-quality RCTs. Furthermore, most studies primarily involve patients with low to moderate disease activity, prompting future investigations into HIIT's effects on individuals with high disease activity. Longitudinal studies are warranted to investigate the long-term impacts of HIIT on IA patients. Moreover, with recent advancements in technology and digital

rehabilitation, exploring self-administered HIIT interventions as a cost-effective alternative to supervised clinical rehabilitation holds potential and warrants further investigation.

Conclusion

High-intensity interval training shows promise as a therapeutic exercise intervention for patients with IA. While evidence suggests benefits in improving health outcomes, concerns persist among patients and healthcare professionals regarding potential adverse effects. This review found no significant change or slight decrease in disease activity and symptoms. Moreover, all studies assessing cardiorespiratory fitness reported increased aerobic capacity, alongside positive changes in health-related quality of life.

Supplementary Information

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Supplementary Material 1

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Data availability
The datasets used and/ or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

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