

# **The anti-inflammatory effects of exercise on autoimmune diseases: A twenty-year systematic review**

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Running title: Anti-inflammatory effects of exercise on autoimmune diseases

## **Supplementary materials**

Supplementary Table 1 Search strategy

Supplementary Table 2 Exercise protocol and safety information of included studies

Supplementary Table 3 Quality assessment of included studies via TESTEX scale

Supplementary Table 4 PRISMA 2020 Checklist

Supplementary Fig. 1 The overall risk of bias for included RCTs

Supplementary Fig. 2 The risk of bias for each included RCT



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- (Pemphigus[Title/Abstract]))
- #2 (((((((((((((((((((((((((((((((Physical activity[MeSH Terms]) OR (Exercise[MeSH Terms])) OR (Physical activit\*[Title/Abstract])) OR (Exercis\*[Title/Abstract])) OR (Training\*[Title/Abstract])) OR (Aerobic exercise\*[Title/Abstract])) OR (Anaerobic exercise\*[Title/Abstract])) OR (Cardiorespiratory fitness[Title/Abstract])) OR (Endurance[Title/Abstract])) OR (Isometric exercise\*[Title/Abstract])) OR (Resistance exercise\*[Title/Abstract])) OR (High intensity exercise Interval training[Title/Abstract])) OR (HIIT[Title/Abstract])) OR (Muscle strengthening[Title/Abstract])) OR (Stretching[Title/Abstract])) OR (Chinese traditional exercise[Title/Abstract])) OR (Tai Ji[Title/Abstract])) OR (Taiji[Title/Abstract])) OR (Tai Chi[Title/Abstract])) OR (Taichi[Title/Abstract])) OR (Taijiquan[Title/Abstract])) OR (Taichichuan[Title/Abstract])) OR (Baduanjin[Title/Abstract])) OR (Qigong[Title/Abstract])) OR (Yijinjing[Title/Abstract])) OR (Liuzijue[Title/Abstract])) OR (Wuqinxi[Title/Abstract]))
- #3 (((((((((((((((((((((((((((((((Inflammation[MeSH Terms]) OR (Inflammation[All Fields])) OR (inflammatory[All Fields])) OR (IFN[All Fields])) OR (Interferons[All Fields])) OR (Interferon[All Fields])) OR (TNF[All Fields])) OR (Tumor necrosis factor[All Fields])) OR (IL[All Fields])) OR (Interleukin[All Fields])) OR (TGF[All Fields])) OR (CRP[All Fields])) OR (C-reactive protein[All Fields])) OR (Cytokines[All Fields])) OR (Cytokine[All Fields])) OR (Chemokines[All Fields])) OR (Chemokine[All Fields])) OR (Lymphocyte[All Fields]))
- #4 #1 AND #2 AND #3
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There were 3331 records identified through PubMed database searching



TS=(TNF)) OR TS=(Tumor necrosis factor)) OR TS=(IL)) OR TS=(Interleukin)) OR TS=(TGF)) OR TS=(CRP)) OR  
TS=(C-reactive protein)) OR TS=(Cytokines)) OR TS=(Cytokine)) OR TS=(Chemokines)) OR TS=(Chemokine)) OR  
TS=(Lymphocyte)

#4 #1 AND #2 AND #3

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There were 5848 records identified through Web of Science database searching.

Search strategy in Embase.

Search	Query
#1	('autoimmune diseases'/exp OR 'autoimmune diseases':ab,ti,kw OR 'rheumatoid arthritis':ab,ti,kw OR 'polymyositis':ab,ti,kw OR 'dermatomyositis':ab,ti,kw OR 'idiopathic inflammatory myopathies':ab,ti,kw OR 'juvenile idiopathic arthritis':ab,ti,kw OR 'juvenile chronic arthritis':ab,ti,kw OR 'ankylosing spondylitis':ab,ti,kw OR 'axial spondyloarthritis':ab,ti,kw OR 'spondyloarthritis':ab,ti,kw OR 'systemic lupus erythematosus':ab,ti,kw OR 'lupus erythematosus disseminatus':ab,ti,kw OR 'primary sjögren syndrome':ab,ti,kw OR 'sjogrens syndrome':ab,ti,kw OR 'sjogren':ab,ti,kw OR 'sjögren':ab,ti,kw OR 'systemic sclerosis':ab,ti,kw OR 'scleroderma':ab,ti,kw OR 'systemic scleroderma':ab,ti,kw OR 'psoriasis':ab,ti,kw OR 'psoriatic arthritis':ab,ti,kw OR 'type 1 diabetes':ab,ti,kw OR 'autoimmune diabetes':ab,ti,kw OR 'hashimoto disease':ab,ti,kw OR 'thyroiditis':ab,ti,kw OR 'chronic lymphocytic thyroiditis':ab,ti,kw OR 'graves':ab,ti,kw OR 'hashimoto thyroiditis':ab,ti,kw OR 'autoimmune thyroid':ab,ti,kw OR 'inflammatory bowel diseases':ab,ti,kw OR 'inflammatory bowel disease':ab,ti,kw OR 'crohn disease':ab,ti,kw OR 'guillain barre syndrome':ab,ti,kw OR 'guillain-barre syndrome':ab,ti,kw OR 'myasthenia gravis':ab,ti,kw OR 'myasthenia gravis':ab,ti,kw OR 'disseminated sclerosis':ab,ti,kw OR 'arteritis':ab,ti,kw OR 'pemphigoid':ab,ti,kw OR 'pemphigus':ab,ti,kw)
#2	('exercise'/exp OR 'physical activity'/exp OR 'aerobic exercise':ab,ti,kw OR 'anaerobic exercise':ab,ti,kw OR 'cardiorespiratory fitness':ab,ti,kw OR 'endurance':ab,ti,kw OR 'isometric exercise':ab,ti,kw OR 'resistance exercise':ab,ti,kw OR 'high intensity exercise interval training':ab,ti,kw OR 'muscle strengthening':ab,ti,kw OR 'stretching':ab,ti,kw OR 'chinese traditional exercise':ab,ti,kw OR 'tai ji':ab,ti,kw OR 'taichi':ab,ti,kw OR 'taijiquan':ab,ti,kw OR 'taichichuan':ab,ti,kw OR 'baduanjin':ab,ti,kw OR 'qigong':ab,ti,kw OR 'yijinjing':ab,ti,kw OR 'liuzijue':ab,ti,kw OR 'wuqinxi':ab,ti,kw)
#3	('inflammation'/exp OR 'inflammatory' OR 'interferons' OR 'interferon' OR 'tumor necrosis factor' OR 'interleukin' OR 'c-reactive protein' OR 'cytokines' OR 'cytokine' OR 'chemokines' OR 'chemokine' OR 'lymphocyte')
#4	#1 AND #2 AND #3

There were 5386 records identified through EMBASE database searching

**Supplementary Table 2.** Exercise protocol and safety information of included studies

Study	Autoimmune disease	Exercise protocol			Safety (dropout, adverse events)	
		Type	Intensity	Frequency		
Alvarenga-Filho et al. (2016) <sup>16</sup>	MS	Combined RT and AT	RT: $\geq 35\%$ 1RM AT: 60%	2 times/week	60 min/session, 12 weeks	2 dropouts in Ex
Bahmani et al. (2022) <sup>17</sup>	MS	AT	$VO_{2max}$ 50%-70% $HR_{max}$	3 times/week	20-40 min/session, 8 weeks	1 dropout in Ex
Bansi et al. (2013) <sup>18</sup>	MS	AT	60% $VO_{2max}$	5 times/week	30 min/session, 3 weeks	2 dropouts in Ex
Barry et al. (2019) <sup>19</sup>	MS	AT	65%-75% $HR_{max}$	2 times/week	30 min/session, 8 weeks	N/A
Berkowitz et al. (2019) <sup>20</sup>	MS	AT	50% $VO_{2peak}$	N/A	20 min, N/A	1 dropout in Ex (illness)
		AT	80% $VO_{2peak}$	N/A	20 min, N/A	
Briken et al. (2016) <sup>21</sup>	MS	AT	8-12.5W/min	N/A	20 min, N/A	4 dropouts in Ex (mobility difficulties, fatigue, injury unrelated to the study); 1 dropout in Con (mobility difficulties)
			Personalized	2-3 times/week	NA, 9 weeks	
Castellano et al. (2008) <sup>22</sup>	MS	AT	60% $VO_{2peak}$	N/A	30 min, N/A	No dropout
				3 times/week	30 min/session, 8 weeks	
Deckx et al. (2016) <sup>23</sup>	MS	Combined RT and AT	Personalized	5 times/2 weeks	30 min/session, 12 weeks	5 dropouts in Ex (mental problems, relapse, corticosteroid treatment); 6 dropouts in Con (health problems, relapse, quit, corticosteroid treatment)



Study	Autoimmune disease	Exercise protocol				Safety (dropout, adverse events)
		Type	Intensity	Frequency	Duration	
Devasahayam et al. (2021) <sup>24</sup>	MS	AT	N/A	N/A	N/A	N/A
Faramarzi et al. (2020) <sup>25</sup>	MS	Combined RT, AT, stretching, balance, and Pilates	RT: 40%-70% 1RM AT: 50%-70% HR <sub>max</sub>	3 times/week	100 min/session, 12 weeks	2 dropouts in Ex (unwillingness); 4 dropouts in Con (unwillingness, relapse)
Golzari et al. (2010) <sup>26</sup>	MS	Combined RT, AT, and stretching	N/A	24 times/ 8weeks	40-50 min/session, 8 weeks	No dropout
Joisten et al. (2021) <sup>27</sup>	MS	HIIT	95%-100% HR <sub>max</sub>	N/A 3 times/week	15.5 min, N/A 15.5 min/session, 3 weeks	N/A
		AT	65% HR <sub>max</sub>	N/A 3 times/week	24 min, N/A 24 min/session, 3 weeks	
Kierkegaard et al. (2016) <sup>28</sup>	MS	RT	80% 1RM	2 times/week	60 min/session, 12 weeks	3 dropouts in Ex (trigeminal neuralgia, headache, personal reasons)
Kjølhede et al. (2016) <sup>29</sup>	MS	RT	10RM	N/A	30 min, N/A	1 dropout in Ex (temporary pain reactions)
			15RM-6RM	2 times/week	30 min/session, 24 weeks	
Mähler et al. (2018) <sup>30</sup>	MS	AT	65% HR <sub>max</sub>	3 times/week	60 min/session, 4 weeks	1 dropout in Ex
Majdinasab et al. (2018) <sup>31</sup>	MS	AT	60%-70%HR <sub>m</sub> ax	N/A	30 min, N/A	No dropout

Study	Autoimmune disease	Exercise protocol			Safety (dropout, adverse events)	
		Type	Intensity	Frequency		Duration
Mokhtarzade et al. (2017) <sup>32</sup>	MS	AT	60%-75% $W_{max}$ AT: 50%-75%	3 times/week	42-66 min/session, 8 weeks	3 dropouts in Ex (relapse, unwillingness); 2 dropouts in Con (unwillingness) 4 dropouts in Ex (unwillingness, migration, pregnancy);
Mokhtarzade et al. (2021) <sup>33</sup>	MS	Combined RT and AT	HRR RT: RPE 5-8	5 times/week	N/A, 24 weeks	3 dropouts in Con (relapse, unwillingness)
Nieste et al. (2022) <sup>34</sup>	MS	AT	50%-60% $W_{max}$	1 time/day	20-30 min/session, 4 days	1 dropout in Con
Ozkul et al. (2018) <sup>35</sup>	MS	Combined AT and Pilates	60%-80% $HR_{max}$	3 times/week	80 min/session, 8 weeks	3 dropouts in Ex (relapse, work intensity); 2 dropouts in Con (personal reasons)
Schulz et al. (2004) <sup>36</sup>	MS	AT	75% $W_{max}$ AT: 40%-70%	2 times/week	30 min/session, 8 weeks	N/A
Tadayon Zadeh et al. (2020) <sup>37</sup>	MS	Combined AT and RT	$HR_{max}$ RT: Personalized	3 times/week	>30min/session, 8 weeks	No dropout
White et al. (2006) <sup>38</sup>	MS	RT	40-70 MVC AT: 65%-80%	2 times/week	30min/session, 8 weeks	N/A
Acar et al. (2016) <sup>39</sup>	RA	Combined RT and AT	$HR_{max}$ RT: Personalized	3 times/week	60 min, 8 weeks	N/A
Andersson et al. (2020) <sup>40</sup>	RA	Combined RT and AT	AT: 70%-89% $HR_{max}$	3 times/week	40 min, 20 weeks	1 dropout in Con

Study	Autoimmune disease	Exercise protocol				Safety (dropout, adverse events)
		Type	Intensity	Frequency	Duration	
Azeez et al. (2020) <sup>41</sup>	RA	Combined RT and AT	RT: 70%-80% 1RM N/A	7 times/week	N/A, 12 weeks	4 dropouts in Ex; 3 dropouts in Con (didn't return for assessment)
Bartlett et al. (2018) <sup>42</sup>	RA	HIIT	50%-90% VO <sub>2</sub> reserve	3 times/week	30 min/session, 10 weeks	No dropout
Ercan et al. 2023) <sup>43</sup>	RA	AT	60%-80% HR <sub>max</sub>	N/A	30 min, N/A	2 dropouts in Ex
Gautam et al. (2019) <sup>44</sup>	RA	Yoga	N/A	5 times/week	120 min/session, 8 weeks	6 dropouts in Ex (injury, work conflict); 4 dropouts in Con (travelling, work conflict, personal reasons)
Gautam et al. (2020) <sup>45</sup>	RA	Yoga	N/A	5 times/week	120 min/session, 8 weeks	2 dropouts in Ex (job transfer); 2 dropouts in Con (domestic reason)
Joo et al. (2022) <sup>46</sup>	RA	RT	N/A	3 times/week	60 min/session, 12 weeks	4 dropouts in Ex (cancer, relapse, declined to participate); 1 dropout in Con (declined to participate)
Law et al. (2015) <sup>47</sup>	RA	AT Combined RT and AT	AT: 66±9 % HR <sub>max</sub> RT: 80% 1RM	N/A 3 times/week	30 min, N/A 60 min/session, 8 weeks	No dropout
Lozada-Mellado et al. (2022) <sup>48</sup>	RA	Combined RT and AT	AT: 55%-75% HR <sub>max</sub> RT: 50%-65% 1RM	2 times/week	>30 min/session, 24 weeks	3 dropouts in Ex (work issues); 9 dropouts in Con (work issues, unknown)
Pereira Nunes Pinto et al. (2017) <sup>49</sup>	RA	RT	50% and 75% 1RM	N/A	25 min, N/A	No dropout

Study	Autoimmune disease	Exercise protocol			Safety (dropout, adverse events)	
		Type	Intensity	Frequency		Duration
Sarajlic et al. (2018) <sup>50</sup>	RA	Combined RT and AT	AT:60%-85% HR <sub>max</sub> RT:50%-80% 1RM	2 times/week	45 min/session, 2 years	N/A
Stavropoulos-Kalino glou et al. (2013) <sup>51</sup>	RA	Combined RT and AT	AT: 70% HR <sub>max</sub> RT: 70% 1RM	3 times/week	60-70 min/session, 24 weeks	2 dropouts in Ex (ulcer, arrhythmia); 2 dropouts in Con (loss of interest)
Wadley et al. (2014) <sup>52</sup>	RA	AT	70% VO <sub>2max</sub>	3 times/week	30-40 min/session, 12 weeks	N/A
Farinha et al. (2018) <sup>53</sup>	T1D	HIIT RT Combined HIIT and RT	HIIT:50%-90% % HR <sub>max</sub> RT: 8RM	3 times/week	>25 min/session, 10 weeks	No dropout
Galassetti et al. (2006) <sup>54</sup>	T1D	AT	80% VO <sub>2max</sub>	N/A	30 min, N/A	No dropout
Galassetti et al. (2006) <sup>55</sup>	T1D	AT	80% VO <sub>2max</sub>	N/A	30 min, N/A	No dropout
Minnock et al. (2020) <sup>56</sup>	T1D	Combined AT and RT	AT: 80% HRR RT: 80% 1RM	N/A	60 min, N/A	N/A
Minnock et al. (2022) <sup>57</sup>	T1D	Combined AT and RT	AT: 80% HRR RT: 80% 1RM	3 times/week	40 min/session, 12 weeks	No dropout
Nazari et al. (2023) <sup>58</sup>	T1D	Combined AT and RT	AT:50%-75% HR <sub>max</sub>	3 times/week	60 min/session, 16 weeks	2 dropouts in Ex (domestic reason);

Study	Autoimmune disease	Exercise protocol				Safety (dropout, adverse events)
		Type	Intensity	Frequency	Duration	
			RT: N/A			2 dropouts in Con (unwillingness to continue)
Rosa et al. (2008) <sup>59</sup>	T1D	AT	<80% $VO_{2max}$	N/A	30 min, N/A	N/A
Rosa et al. (2010) <sup>60</sup>	T1D	AT	<80% $VO_{2max}$	N/A	30 min, N/A	N/A
Rosa et al. (2011) <sup>61</sup>	T1D	AT	<80% $VO_{2max}$	N/A	30 min, N/A	N/A
Rosa et al. (2011) <sup>62</sup>	T1D	AT	<80% $VO_{2max}$	N/A	30 min, N/A	N/A
Salman et al. (2008) <sup>63</sup>	T1D	AT	N/A	N/A	N/A	N/A
Turner et al. (2014) <sup>64</sup>	T1D	RT	67±3% 1RM	1 time/day	15-45 min/session, 4 days	N/A
Żebrowska et al. (2018) <sup>65</sup>	T1D	AT HIIT	50% LT 120% LT	N/A	40 min, N/A	N/A
Clarke-Jenssen et al. (2005) <sup>66</sup>	SLE	AT	70% $HR_{max}$	3 times/week	25-40 min/session, 12 weeks	No dropout
da Silva et al. (2013) <sup>67</sup>	SLE	AT	N/A	N/A	N/A	N/A
Hashemi et al. (2022) <sup>68</sup>	SLE	Combined AT and RT	AT: 50%-60% $VO_{2peak}$	3 times/week	80 min/session, 8 weeks	5 dropouts in Ex; 1 dropout in Con
Perandini et al. (2014) <sup>69</sup>	SLE	AT	60% $VO_{2peak}$ 40%-60% $VO_{2peak}$	N/A 2 times/week	45 min, N/A 30-50 min/session, 12 weeks	No dropout
Perandini et al. (2015) <sup>70</sup>	SLE	AT	40%-60% $VO_{2peak}$	N/A	30min, N/A	N/A

Study	Autoimmune disease	Exercise protocol			Safety (dropout, adverse events)	
		Type	Intensity	Frequency		Duration
Perandini et al. (2016) <sup>71</sup>	SLE	AT	60%-75% VO <sub>2peak</sub>	N/A	30 min, N/A	N/A
Soriano-Maldonado et al. (2018) <sup>72</sup>	SLE	AT	35%-75% HRR	2 times/week	55-90 min/session, 12 weeks	4 dropouts in Ex (lack of time, sciatica); 4 dropouts in Con (lack of time)
Timóteo et al. (2018) <sup>73</sup>	SLE	Combined RT, AT, and stretching	AT: Personalized RT: 70% 1RM	3 times/week	50 min/session, 16 weeks	No dropout
Aydın et al. (2016) <sup>74</sup>	AS	Calisthenic exercise Combined RT, postural correction and stretching	N/A	5 times/week	60 min/session, 8 weeks	3 dropouts in Ex (failure to adapt to the exercise)
Hulejová et al. (2012) <sup>76</sup>	AS	Combined dance and Pilates Combined core spinal traction and strengthening	N/A	2 times/week	45 min/session, 12 weeks	4 dropouts in Ex
Kisacik et al. (2016) <sup>77</sup>	AS	Combined core spinal traction and strengthening	N/A	3 times/week	60 min/session, 12 weeks	16 dropouts in Ex (pregnant, traffic accident, illness, transportation problems, divorced)
Levitova et al. (2016) <sup>78</sup>	AS	Tai Chi	N/A	2 times/week	60 min/session, 24 weeks	6 dropouts in Ex (illness, peripheral arthritis)
Ma et al. (2020) <sup>79</sup>	AS	Tai Chi	N/A	3 times/week	30-40 min/session, 12 weeks	No dropout

Study	Autoimmune disease	Exercise protocol			Safety (dropout, adverse events)	
		Type	Intensity	Frequency		Duration
Nolte et al. (2021) <sup>80</sup>	AS	Combined AT, RT and stretching	N/A	3 times/week	N/A, 24 weeks	4 dropouts in Ex (time constraints, travelling, work commitments); 5 dropouts in Con (time constraints, travelling)
de Souza et al. (2017) <sup>75</sup>	AS	RT	50%-70% 1RM	2 times/week	50 min/session, 16 weeks	3 dropouts in Ex (rupture of calcaneus tendon and pain); 2 dropouts in Con (loss of contact of calcaneus tendon)
Sveaas et al. (2020) <sup>81</sup>	AS	Combined HIIT and RT	RT: 8-10 RM HIIT: 70-95% HR <sub>max</sub>	3 times/week	40-60 min/session, 12 weeks	2 dropouts in Ex (chest pain, nausea, persistent pain during exercise); 1 dropout in Con
Alexanderson et al. (2007) <sup>82</sup>	IIM	RT	10 RM	3 times/week	45 min/session, 7 weeks	1 dropout in Ex (influenza-like symptoms)
Alexanderson et al. (2014) <sup>83</sup>	IIM	RT	N/A	5 times/week	>20 min/session, 24 weeks	2 dropouts in Ex (ovarian cancer, alveolitis)
Arnardottir et al. (2003) <sup>84</sup>	IIM	Combined AT and RT	N/A	5 times/week	30 min/session, 12 weeks	N/A
Coudert et al. (2022) <sup>85</sup>	IIM	Combined AT and RT	N/A	3 times/week	30-60 min/session, 26 weeks	N/A
Švec et al. (2022) <sup>86</sup>	IIM	RT and stability training	N/A	2 times/week	60 min/session, 24 weeks	No dropout
Bjelica et al. (2023) <sup>87</sup>	IBD	Combined AT and RT	N/A	3 times/week	30-60 min/session, 16 weeks	1 dropout in Ex

Study	Autoimmune disease	Exercise protocol				Safety (dropout, adverse events)
		Type	Intensity	Frequency	Duration	
Cronin et al. et al. (2019) <sup>88</sup>	IBD	Combined AT and RT	AT: RPE 5-7	3 times/week	>20 min/session, 8 week	2 dropouts in Ex (personal reasons, time constraints); 2 dropouts in Con (pregnant)
Klare et al. (2015) <sup>89</sup>	IBD	AT	Moderate intensity	3 times/week	N/A, 10 weeks	3 dropouts in Ex (lack of motivation, injury, mild abdominal symptoms); 3 dropouts in Con (didn't attend follow-up)
Lamers et al. (2021) <sup>90</sup>	IBD	AT	60%-70% HR <sub>max</sub>	1 time/day	>30 min/session, 4 days	2 dropouts in Ex (fall, abdominal pain and frequent loose stools)
Legeret et al. (2019) <sup>91</sup>	IBD	Exercise games (dance, AT)	N/A	5 times/week	30 min/session, 8 weeks	N/A
Scheffers et al. (2023) <sup>92</sup>	IBD	Combined AT and RT	N/A	3 times/week	60 min/session, 12 weeks	1 dropout in Ex
Astley et al. (2021) <sup>93</sup>	TA	Combined AT and RT	N/A	3 times/week	NA, 12 weeks	3 dropouts in Con (personal reasons)
Li et al. (2020) <sup>94</sup>	TA	RT	60%-80% 1RM	2 times/week	60 min/session, 12 weeks	7 dropouts in Ex; 9 dropouts in Con (personal reasons or noncompliance)
Oliveira et al. (2017) <sup>95</sup>	TA	AT	60% VO <sub>2peak</sub>	N/A	45 min, N/A	N/A
Rochette et al. (2018) <sup>96</sup>	JIA	AT	N/A	2 times/week	30-50 min/session, 12 weeks	N/A
			70% HR <sub>max</sub>	N/A	20 min, N/A	No dropout



Study	Autoimmune disease	Exercise protocol			Safety (dropout, adverse events)	
		Type	Intensity	Frequency		Duration
Rochette et al. (2018) <sup>97</sup>	JIA	AT	70% HR <sub>max</sub>	N/A	20 min, N/A	No dropout
Timóteo et al. (2019) <sup>98</sup>	PF	Combined RT and stretching	RT: 70% 1RM	3 times/week	60 min/session, 12 weeks	N/A
Hargadóttir et al. (2010) <sup>99</sup>	SSc	AT	N/A	N/A	8-12 min, N/A	N/A
Pool et al. (2004) <sup>100</sup>	RA and SLE	AT	N/A	N/A	N/A	No dropout
Sandstad et al. (2015) <sup>101</sup>	RA and JIA	HIIT	70%-95% HR <sub>max</sub>	2 times/week	35 min/session, 10 weeks	3 dropouts in Ex (migration, arthritis); 4 dropouts in Con (migration, pregnant)
Taspınar et al. (2015) <sup>102</sup>	AS and MS	Calisthenic exercise	N/A	5 times/week	60 min/session, 8 weeks	4 dropouts in Ex

Abbreviations: Ex = exercise group; Con = control group; HRR: heart rate reserve; HR<sub>max</sub> = maximum heart rate; RM = repetition maximum; RPE = rate of perceived exertion; LT = lactate threshold; MVC = maximal voluntary isometric contraction; N/A = not applicable; VO<sub>2max</sub> = maximal oxygen uptake; VO<sub>2peak</sub> = peak oxygen uptake; VO<sub>2reserve</sub> = oxygen uptake reserve; W<sub>max</sub> = maximum watts.

**Supplementary Table 3.** Quality assessment of included studies via TESTEX scale

Study ( <i>n</i> = 87)	Score												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Acar et al. (2016) <sup>39</sup>	NRCT	1	0	0	0	0	1	0	2	1	1	1	1
Alexanderson et al. (2007) <sup>82</sup>	NRCT	1	0	0	0	0	1	0	0	1	0	1	1
Alexanderson et al. (2014) <sup>83</sup>	RCT	1	1	0	1	1	3	1	2	1	1	0	1
Alvarenga-Filho et al. (2016) <sup>16</sup>	NRCT	1	0	0	1	0	1	0	2	1	0	1	1
Andersson et al. (2020) <sup>40</sup>	RCT	1	1	1	0	1	1	0	2	1	0	0	1
Arnardottir et al. (2003) <sup>84</sup>	NRCT	1	0	0	0	0	1	0	0	1	0	0	0
Astley et al. (2021) <sup>93</sup>	RCT	1	1	0	1	1	2	0	2	1	0	1	0
Aydin et al. (2016) <sup>74</sup>	RCT	1	1	0	1	0	2	0	2	1	0	0	0
Azeez et al. (2020) <sup>41</sup>	RCT	1	1	0	1	0	1	0	2	1	0	1	1
Bahmani et al. (2022) <sup>17</sup>	RCT	1	1	0	0	0	1	0	2	1	0	1	1
Bansi et al. (2013) <sup>18</sup>	RCT	1	0	0	1	0	1	0	2	1	0	0	1
Barry et al. (2019) <sup>19</sup>	NRCT	1	0	0	0	0	1	0	2	1	0	0	0
Bartlett et al. (2018) <sup>42</sup>	NRCT	1	0	0	0	0	1	0	0	1	0	0	0
Berkowitz et al. (2019) <sup>20</sup>	NRCT	1	0	0	0	0	1	0	2	1	0	1	1
Bjelica et al. (2023) <sup>87</sup>	NRCT	1	0	0	0	0	3	0	0	1	0	1	1
Briken et al. (2016) <sup>21</sup>	RCT	1	1	1	1	0	2	0	2	1	0	1	1

Study (n = 87)	Score												Total	
	1	2	3	4	5	6	7	8	9	10	11	12		
Castellano et al. (2008) <sup>22</sup>	NRCT	1	0	0	0	0	0	0	0	1	1	0	0	1
Clarke-Jenssen et al. (2005) <sup>66</sup>	NRCT	1	0	0	0	0	0	1	0	0	1	0	1	1
Coudert et al. (2022) <sup>85</sup>	RCT	1	1	1	0	1	1	0	0	0	1	1	1	1
Cronin et al. et al. (2019) <sup>88</sup>	RCT	1	1	0	1	0	2	0	2	1	1	1	1	1
da Silva et al. (2013) <sup>67</sup>	NRCT	1	0	0	0	0	0	1	0	2	1	0	0	0
de Souza et al. (2017) <sup>75</sup>	RCT	1	1	1	1	1	1	2	1	2	1	0	0	1
Deckx et al. (2016) <sup>23</sup>	RCT	1	1	0	1	1	1	1	0	2	1	0	0	1
Devasahayam et al. (2021) <sup>24</sup>	NRCT	1	0	0	0	0	0	1	0	2	1	0	1	1
Ercan et al. (2023) <sup>43</sup>	NRCT	1	0	0	0	0	0	1	0	2	1	0	1	1
Famarzi et al. (2020) <sup>25</sup>	RCT	1	0	0	0	0	1	3	0	2	1	0	1	1
Farinha et al. (2018) <sup>53</sup>	RCT	1	1	0	1	1	1	2	0	2	1	0	1	1
Galassetti et al. (2006) <sup>54</sup>	NRCT	1	0	0	0	0	0	1	0	2	1	0	0	1
Galassetti et al. (2006) <sup>55</sup>	NRCT	1	0	0	0	0	0	1	0	2	1	0	0	1
Gautam et al. (2019) <sup>44</sup>	RCT	1	1	1	1	1	1	1	1	2	1	0	0	0
Gautam et al. (2020) <sup>45</sup>	RCT	1	1	1	1	1	1	1	1	2	1	0	0	0
Golzari et al. (2010) <sup>26</sup>	RCT	1	0	0	0	0	0	1	0	0	0	1	1	1
Hargardóttir et al. (2010) <sup>99</sup>	NRCT	1	0	0	0	0	0	1	0	2	1	0	0	1
Hashemi et al. (2022) <sup>68</sup>	RCT	1	0	0	0	1	0	0	0	2	1	0	0	1

Study (n = 87)	Score												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Hulejová et al. (2012) <sup>76</sup>	NRCT	1	0	0	0	0	1	0	0	1	0	0	1
Joisten et al. (2021) <sup>27</sup>	RCT	1	1	0	1	0	0	0	2	1	0	0	1
Joo et al. (2022) <sup>46</sup>	NRCT	1	0	0	1	0	2	0	2	1	0	1	0
Kierkegaard et al. (2016) <sup>28</sup>	NRCT	1	0	0	0	0	3	0	0	1	0	0	1
Kisacik et al. (2016) <sup>77</sup>	NRCT	1	0	0	0	0	0	1	0	1	0	0	0
Kjølhede et al. (2016) <sup>29</sup>	RCT	1	1	1	1	0	3	0	2	1	0	0	1
Klare et al. (2015) <sup>89</sup>	RCT	1	1	0	1	0	2	0	2	1	0	0	1
Lamers et al. (2021) <sup>90</sup>	NRCT	1	0	0	0	0	1	0	2	1	0	0	1
Law et al. (2015) <sup>47</sup>	NRCT	1	0	0	0	0	1	0	2	1	0	1	1
Legeret et al. (2019) <sup>91</sup>	NRCT	1	0	0	0	0	1	0	2	1	0	0	1
Levitova et al. (2016) <sup>78</sup>	NRCT	1	0	0	0	0	1	0	2	1	0	0	1
Li et al. (2020) <sup>94</sup>	RCT	1	1	0	1	0	1	0	2	1	0	1	1
Lozada-Mellado et al. (2022) <sup>48</sup>	RCT	1	1	0	1	1	2	0	2	1	0	1	1
Ma et al. (2020) <sup>79</sup>	RCT	1	0	0	1	0	1	0	2	1	0	0	0
Mähler et al. (2018) <sup>30</sup>	RCT	1	0	0	1	0	1	0	2	1	0	1	1
Majdinasab et al. (2018) <sup>31</sup>	NRCT	1	0	0	0	0	1	0	2	1	0	0	1
Minnock et al. (2020) <sup>56</sup>	RCT	1	0	0	0	0	1	0	2	1	1	0	0
Minnock et al. (2022) <sup>57</sup>	NRCT	1	0	0	0	0	1	0	2	1	0	0	1
Mokhtarzade et al. (2017) <sup>32</sup>	RCT	1	0	0	1	0	1	0	2	1	0	1	1

Study (n = 87)	Score												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Mokhtarzade et al. (2021) <sup>33</sup>	RCT	1	0	1	1	0	2	1	2	1	0	1	1
Nazari et al. (2023) <sup>58</sup>	RCT	1	1	0	1	0	2	0	2	1	0	0	1
Nieste et al. (2022) <sup>34</sup>	RCT	1	1	1	1	0	1	0	2	1	1	1	1
Nolte et al. (2021) <sup>80</sup>	RCT	1	1	0	1	0	0	0	2	1	0	1	1
Oliveira et al. (2017) <sup>95</sup>	NRCT	1	0	0	0	0	2	0	2	1	0	1	1
Ozkul et al. (2018) <sup>35</sup>	RCT	1	1	0	1	1	2	0	2	1	0	1	1
Perandini et al. (2014) <sup>69</sup>	NRCT	1	0	0	0	0	1	0	2	1	0	1	1
Perandini et al. (2015) <sup>70</sup>	NRCT	1	0	0	0	0	1	0	2	1	0	0	1
Perandini et al. (2016) <sup>71</sup>	NRCT	1	0	0	0	0	1	0	2	1	0	0	1
Pereira Nunes Pinto et al. (2017) <sup>49</sup>	NRCT	1	0	0	0	0	1	0	2	1	0	0	1
Pool et al. (2004) <sup>100</sup>	NRCT	1	0	0	0	0	1	0	2	1	0	0	1
Rochette et al. (2018) <sup>96</sup>	NRCT	1	0	0	0	0	1	0	0	1	0	0	1
Rochette et.al (2018) <sup>97</sup>	NRCT	1	0	0	0	0	1	0	0	1	0	0	1
Rosa et al. (2008) <sup>59</sup>	NRCT	1	0	0	0	0	0	0	2	1	0	0	1
Rosa et al. (2010) <sup>60</sup>	NRCT	1	0	0	0	0	0	0	0	1	0	0	1
Rosa et al. (2011) <sup>61</sup>	NRCT	1	0	0	0	0	1	0	2	1	1	0	1
Rosa et al. (2011) <sup>62</sup>	NRCT	1	0	0	0	0	1	0	2	1	1	0	1
Salman et al. (2008) <sup>63</sup>	NRCT	1	0	0	0	0	1	0	2	1	0	0	1
Sandstad et al. (2015) <sup>101</sup>	RCT	1	0	0	1	0	1	0	2	1	0	1	1
Sarajlic et al. (2018) <sup>50</sup>	NRCT	1	0	0	1	0	1	0	0	1	1	0	1

Study (n = 87)	Score												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Scheffers et al. (2023) <sup>92</sup>	RCT	1	0	0	0	0	3	0	2	1	1	1	1
Schulz et al. (2004) <sup>36</sup>	RCT	1	0	0	1	0	1	0	2	1	0	1	1
Soriano-Maldonado et al. (2018) <sup>72</sup>	NRCT	1	0	0	1	0	3	1	2	1	0	1	1
Stavropoulos-Kalinoglou et al. (2013) <sup>51</sup>	NRCT	1	0	0	1	0	3	0	2	1	0	1	1
Sveaas et al. (2020) <sup>81</sup>	RCT	1	1	1	1	1	3	0	2	1	1	0	0
Švec et al. (2022) <sup>86</sup>	NRCT	1	0	0	0	0	1	0	2	1	0	0	1
Tadayon Zadeh et al. (2020) <sup>37</sup>	RCT	1	0	0	1	0	2	0	2	1	0	1	1
Taspinar et al. (2015) <sup>102</sup>	RCT	1	1	0	1	0	1	0	2	1	1	0	0
Timóteo et al. (2018) <sup>73</sup>	NRCT	1	0	0	0	0	1	0	2	1	0	0	1
Timóteo et al. (2019) <sup>98</sup>	NRCT	1	0	0	1	0	1	0	2	1	0	0	1
Turner et al. (2014) <sup>64</sup>	NRCT	1	1	0	0	0	1	0	0	1	0	0	1
Wadley et al. (2014) <sup>52</sup>	RCT	1	0	0	1	0	1	0	2	1	0	1	1
White et al. (2006) <sup>38</sup>	NRCT	1	0	0	0	0	1	0	0	1	0	1	1
Żebrowska et al. (2018) <sup>65</sup>	NRCT	1	0	0	0	0	1	0	2	1	0	0	1

Abbreviations: RCT = randomized controlled trial; NRCT = non-randomized controlled trial.

**Supplementary Table 4. PRISMA 2020 Checklist**

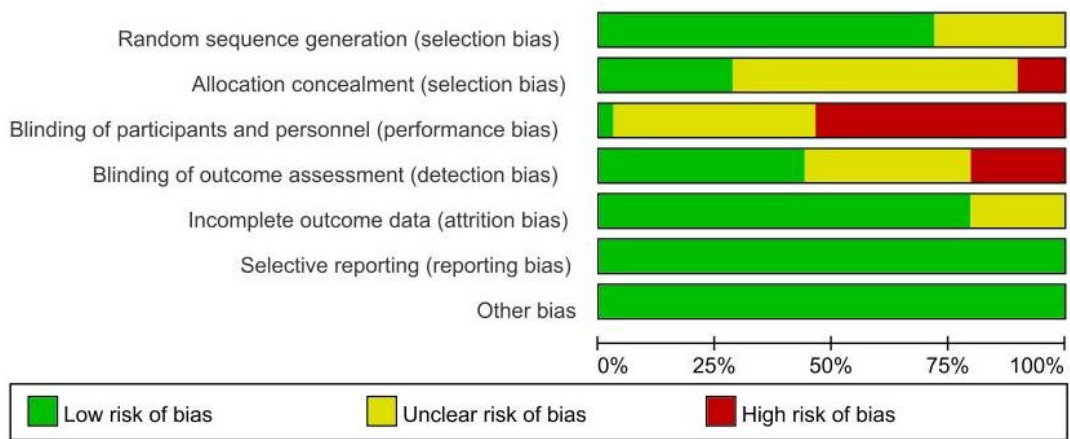
Section and Topic	Item #	Checklist item	Location where item is reported
<b>TITLE</b>			
Title	1	Identify the report as a systematic review.	Page 1
<b>ABSTRACT</b>			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 1-2
<b>INTRODUCTION</b>			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page 2-3
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page 2
<b>METHODS</b>			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Page 3-4 Table 1
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page 3
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Suppl Table 1
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Page 4
Data collection	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether	Page 4

process		they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Page 4
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page 4
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Page 5
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	N/A
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Page 4
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	N/A
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Page 4
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Page 4
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	N/A
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	N/A
Reporting bias	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Page 5



assessment			
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Page 5
<b>RESULTS</b>			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Page 5 Figure 1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Figure 1
Study characteristics	17	Cite each included study and present its characteristics.	Page 11-18 Table 1
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Suppl Table 3, Suppl Figure 2
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Table 1
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Page 6-9
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Table 1
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	N/A
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	N/A
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Suppl Figure 1

Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Page 8-9
<b>DISCUSSION</b>			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Page 9
	23b	Discuss any limitations of the evidence included in the review.	Page 10
	23c	Discuss any limitations of the review processes used.	Page 10
	23d	Discuss implications of the results for practice, policy, and future research.	Page 10
<b>OTHER INFORMATION</b>			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page 1
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	N/A
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	N/A
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page 11
Competing interests	26	Declare any competing interests of review authors.	Page 11
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Page 11



**Supplementary Fig. 1.** The overall risk of bias for included RCTs

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Alexanderson 2014 <sup>83</sup>	+	+	+	+	+	+	+
Andersson 2020 <sup>60</sup>	+	+	?	+	?	+	+
Astley 2021 <sup>93</sup>	+	?	+	+	+	+	+
Aydin 2016 <sup>74</sup>	+	?	?	?	+	+	+
Azeez 2020 <sup>41</sup>	+	?	?	?	+	+	+
Bahmani 2022 <sup>17</sup>	+	?	?	?	?	+	+
Bansi 2012 <sup>18</sup>	?	?	?	+	+	+	+
Briken 2016 <sup>21</sup>	+	+	?	+	+	+	+
Coudert 2022 <sup>85</sup>	+	+	?	+	?	+	+
Cronin 2019 <sup>88</sup>	+	+	+	+	+	+	+
Deckx 2017 <sup>75</sup>	?	?	+	+	+	+	+
de Souza 2016 <sup>23</sup>	+	+	+	+	+	+	+
Faramarzi 2020 <sup>28</sup>	?	+	+	+	+	+	+
Farinha 2018 <sup>53</sup>	+	?	?	+	+	+	+
Gautam 2019 <sup>44</sup>	+	?	+	+	+	+	+
Gautam 2020 <sup>45</sup>	+	?	+	+	+	+	+
Golzari 2010 <sup>26</sup>	?	?	?	?	+	+	+
Hashemi 2022 <sup>68</sup>	?	?	?	?	?	+	+
Joisten 2021 <sup>27</sup>	+	?	?	?	?	+	+
Kjelhede 2016 <sup>29</sup>	+	+	+	?	+	+	+
Klare 2015 <sup>89</sup>	+	?	+	?	+	+	+
Li 2020 <sup>94</sup>	+	?	?	+	+	+	+
Lozada-Mellado 2022 <sup>48</sup>	+	+	?	+	+	+	+
Ma 2020 <sup>78</sup>	+	?	?	?	?	+	+
Mähler 2018 <sup>30</sup>	+	?	+	+	+	+	+
Minnock 2020 <sup>56</sup>	?	+	?	?	?	+	+
Mokhtarzade 2017 <sup>33</sup>	?	?	?	?	+	+	+
Mokhtarzade 2021 <sup>32</sup>	+	+	+	+	+	+	+
Nazari 2023 <sup>58</sup>	+	+	+	+	+	+	+
Nieste 2022 <sup>34</sup>	+	+	+	+	+	+	+
Nolte 2021 <sup>80</sup>	+	?	+	+	+	+	+
Ozkul 2018 <sup>35</sup>	+	?	+	+	+	+	+
Sandstad 2015 <sup>101</sup>	?	?	?	?	+	+	+
Scheffers 2023 <sup>92</sup>	+	+	+	+	+	+	+
Schulz 2004 <sup>36</sup>	?	?	?	?	?	+	+
Sveaas 2020 <sup>81</sup>	+	+	+	+	+	+	+
Tadayon Zadeh 2020 <sup>37</sup>	?	?	?	?	+	+	+
Taspinar 2015 <sup>102</sup>	+	?	+	+	+	+	+
Wadley 2014 <sup>52</sup>	?	?	?	?	+	+	+

Supplementary Fig. 2. The risk of bias for each included RCTs