

ORIGINAL RESEARCH

Effects of physical exercise and body weight on disease-specific outcomes of people with rheumatic and musculoskeletal diseases (RMDs): systematic reviews and meta-analyses informing the 2021 EULAR recommendations for lifestyle improvements in people with RMDs

James M Gwinnutt ¹, Maud Wiecezorek ^{2,3}, Giulio Cavalli ⁴, Andra Balanescu,⁵ Heike A Bischoff-Ferrari,^{3,6,7} Annelies Boonen ^{8,9}, Savia de Souza,¹⁰ Annette de Thurah ^{11,12}, Thomas E Dorner,^{13,14,15} Rikke Helene Moe ¹⁶, Polina Putrik,^{8,9} Javier Rodríguez-Carrio ^{17,18}, Lucía Silva-Fernández,¹⁹ Tanja Stamm ^{20,21}, Karen Walker-Bone,²² Joep Welling,²³ Mirjana I Zlatković-Švenda ^{24,25}, Francis Guillemin ^{2,26}, Suzanne M M Verstappen^{1,22,27}

To cite: Gwinnutt JM, Wiecezorek M, Cavalli G, *et al*. Effects of physical exercise and body weight on disease-specific outcomes of people with rheumatic and musculoskeletal diseases (RMDs): systematic reviews and meta-analyses informing the 2021 EULAR recommendations for lifestyle improvements in people with RMDs. *RMD Open* 2022;**8**:e002168. doi:10.1136/rmdopen-2021-002168

► Additional supplemental material is published online only. To view, please visit the journal online (<http://dx.doi.org/10.1136/rmdopen-2021-002168>).

Received 17 December 2021
Accepted 23 February 2022



© Author(s) (or their employer(s)) 2022. Re-use permitted under CC BY. Published by BMJ.

For numbered affiliations see end of article.

Correspondence to

Dr Suzanne M M Verstappen; suzanne.verstappen@manchester.ac.uk

ABSTRACT

Background A European League Against Rheumatism (EULAR) taskforce was convened to develop recommendations for lifestyle behaviours in rheumatic and musculoskeletal diseases (RMDs). This paper reviews the literature on the effects of physical exercise and body weight on disease-specific outcomes of people with RMDs.

Methods Three systematic reviews were conducted to summarise evidence related to exercise and weight in seven RMDs: osteoarthritis, rheumatoid arthritis, systemic lupus erythematosus, axial spondyloarthritis (axSpA), psoriatic arthritis, systemic sclerosis and gout. Systematic reviews and original studies were included if they assessed exercise or weight in one of the above RMDs, and reported results regarding disease-specific outcomes (eg, pain, function, joint damage). Systematic reviews were only included if published between 2013–2018. Search strategies were implemented in the Medline, Embase, Cochrane Library of systematic reviews and CENTRAL databases.

Results 236 articles on exercise and 181 articles on weight were included. Exercise interventions resulted in improvements in outcomes such as pain and function across all the RMDs, although the size of the effect varied by RMD and intervention. Disease activity was not influenced by exercise, other than in axSpA. Increased body weight was associated with worse outcomes for the majority of RMDs and outcomes assessed. In general, study quality was moderate for the literature on exercise

Key messages

What is already known about this subject?

- Body weight and physical exercise are important for health.
- It is unclear whether body weight or change in body weight and exercise influence outcomes in rheumatic and musculoskeletal diseases (RMDs).

What does this study add?

- This study summarises the literature on the association between exercise and weight with disease outcomes of seven RMDs, concluding that performing exercise and a healthy weight are associated with better outcomes in people with RMDs.

How might this impact on clinical practice or further developments?

- People with RMDs should be encouraged to perform exercise if they do not currently perform exercise, or maintain exercise if performing sufficient quantities.
- People with RMDs should be encouraged and supported to attain and maintain a healthy body weight.

and body weight in RMDs, although there was large heterogeneity between studies.

Conclusion The current literature supports recommending exercise and the maintenance of a healthy body weight for people with RMDs.

INTRODUCTION

Rheumatic and musculoskeletal diseases (RMDs) comprise a wide range of conditions characterised by pain, disability and poorer quality of life (QoL).^{1–3} Globally, these conditions comprise a significant burden which is continuing to increase. For instance, the Global Burden of Disease study reported that the percentage increase of disability adjusted life years driven by RMDs (other than lower back pain) was 128.9% (95% CI 122.0% to 136.3%) between 1990 and 2019 across all age groups.⁴ While some RMDs have many effective pharmacological treatments (eg, rheumatoid arthritis (RA)⁵), for some the treatment options are limited (eg, systemic lupus erythematosus (SLE)⁶) and for others there are no effective disease modifying treatments (eg, osteoarthritis (OA)⁷). However, there is room for additional improvements in outcomes in all RMDs, potentially through modification of lifestyle behaviour.

Physical activity (including exercise)⁸ is clearly beneficial for health, regardless of the presence of chronic diseases such as RMDs. The WHO and American institutions recommend that all adults aged 18–65 years should participate in at least 150 min per week of moderate-intensity aerobic physical activity, or do at least 75 min of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity activity (moderate intensity=3.0 to <6.0 METs (metabolic equivalent of task), vigorous intensity =≥6 METs, where 1 MET is the rate of energy expenditure at rest). Additionally, all adults aged 18–65 years should perform muscle-strengthening activities (eg, resistance training and weight lifting) involving major muscle groups on two or more days a week.^{9 10} In 2018, the European League Against Rheumatism (EULAR) recommended physical activity for people with inflammatory arthritis and OA,¹¹ after a systematic review illustrating the benefits of exercise on strength, flexibility and cardiovascular fitness.¹² Furthermore, exercise is closely linked to body weight. The prevalence of global obesity is increasing and obesity, as well as physical inactivity, is associated with poor health, comorbidity (eg, cardiovascular disease,¹³ diabetes,¹⁴) and increased risk of mortality.¹³ Therefore, there is an urgent need for strategies to ameliorate the obesity epidemic for the benefit of global health.

However, it is unclear whether exercise is effective at improving RMD-specific outcomes (eg, pain, disability), or whether excess weight is associated with worse RMD outcomes. Therefore, a EULAR taskforce was convened in 2018 to develop recommendations for lifestyle improvements in RMDs, with the focus on lifestyles that affect disease progression. The taskforce decided to focus on six lifestyle factors: diet, exercise, body weight, alcohol, smoking and (paid) work-participation, in seven diseases: RA, OA, SLE, axial spondyloarthritis (axSpA), psoriatic arthritis (PsA), systemic sclerosis (SSc) and gout (henceforth referred to collectively as RMDs). For each of these lifestyle factors, systematic reviews were performed, aiming to collate all relevant literature on each factor in

order to formulate evidence-based recommendations. This article presents the results of the systematic reviews assessing the impact of exercise and body weight on the disease-specific outcomes of people with RMDs.

METHODS

Design

These reviews were conducted following EULAR's standard operating procedure for EULAR endorsed recommendations¹⁵ and are reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.¹⁶

Search strategy

A two-step process was used to identify studies to include in each review. Initially, a review of systematic reviews was conducted using the MEDLINE, EMBASE and Cochrane Library databases, aiming to identify existing systematic reviews on the included exposures and RMD progression (online supplemental tables 1 and 2, defined a priori by the study team) that were published from 1 January 2013 to 18 September 2018. Two reviewers screened the titles and abstracts (JMG and MW) and then a team of four reviewers screened the eligible full texts (JMG, MW, JR-C and GC; each full text screened by two reviewers). Only existing systematic reviews relating to exercise and weight are presented here.

Following this, separate systematic reviews of original studies of exercise and weight in RMDs were conducted (from inception to search date). It was decided that there were sufficient numbers of published systematic reviews regarding exercise and OA and therefore OA was not included in the systematic review of original studies of exercise. Search strategies for each review were developed based on a predefined PICO strategy (participants, intervention/exposure, comparison, outcome) (online supplemental tables 3 and 4 for search strategies) and implemented in the MEDLINE, EMBASE and CENTRAL databases (dates when strategies were implemented: exercise: 18 March 2019; weight: 14 March 2019). Titles and abstracts, followed by full texts, were screened by two reviewers (exercise: JMG and GC; weight: JMG and SMMV).

Inclusion and exclusion criteria

Systematic reviews were included if they:

- ▶ Included adults with an RMD (OA, RA, SLE, axSpA, PsA, SSc, gout).
- ▶ Studied the relationship between exercise or weight and disease-specific outcomes (online supplemental table 5 for list of included outcomes).
- ▶ Published in English, French, Spanish or Italian.

No restrictions were implemented regarding the included study designs of studies in systematic reviews.

Original studies were included if they:

- ▶ Used a longitudinal study design (randomised controlled trials (RCTs), non-randomised trials,

single-arm intervention studies, longitudinal observational studies)

- ▶ Included adults with an RMD (RA, SLE, axSpA, PsA, SSc, gout (and OA for the weight review)).
- ▶ Studied the relationship between exercise or weight and outcomes (online supplemental table 5 for list of included outcomes).
- ▶ Published in English, French, Spanish or Italian. Conference abstracts were excluded.

Risk of bias assessment

To assess the risk of bias of included systematic reviews and meta-analyses, the AMSTAR-2 tool was used.¹⁷ Each included review or meta-analysis was rated as critically low, low, moderate or high quality. For included RCTs, an abbreviated version of the Cochrane Risk of Bias tool was used,¹⁸ assessing four criteria: randomisation procedure, allocation concealment procedure, blinding of participants and blinding of assessors. Each aspect was rated as either low or high/unclear risk of bias. A machine learning algorithm was used to assist the process,¹⁹ which identifies passages of text from included manuscripts and assigns grades for each criteria. A reviewer (JMG) checked each of the algorithm's grades and if there was disagreement, changed the grade. The QUIPS tool was used to assess the quality of observational studies across six domains: study population, attrition, exposure measurement, outcome measurement, confounding and statistical analysis.²⁰

Synthesis of data

Data from articles were extracted into prespecified tables, including study design, demographics, and results of outcomes and follow-up. The data from the individual articles are presented in the form of a narrative summary. Where possible, the mean and SD were extracted. SDs were estimated from 95% CIs or SEs when not reported. Means and SDs were estimated from medians and range/IQR when only these summary statistics were presented using published formulas.²¹ Furthermore, standardised mean differences (SMD) were calculated for individual studies as this allows results measured on different instruments to be compared and combined (SMDs provided in online supplemental materials). The SMD was estimated as the difference between the scores of the intervention and control group at follow-up divided by the pooled SD. Meta-analysis was used to combine the results of RCTs where possible. An SMD ≥ 0.2 was considered a small effect, ≥ 0.5 as a medium-sized effect and ≥ 0.8 as a large effect.²² Heterogeneity was quantified using the I^2 statistic. All statistical analyses were performed using Stata V.14 (StataCorp).

Grades of Recommendations, Assessment, Development and Evaluation (GRADE) defines high-quality evidence as evidence where further research is very unlikely to change our confidence in the estimate of effect.²³ Therefore, evidence was rated as high quality if supported by meta-analyses of ≥ 5 RCTs at low-moderate

risk of bias reporting consistent results without important limitations.²⁴ GRADE defines moderate quality evidence as evidence where further research is likely to have an important impact on the confidence of the estimate of effect, or may change the estimate.²³ Evidence was rated as moderate if supported by meta-analyses of ≥ 3 RCTs or supported by a single RCT with a sample size ≥ 100 and at low-moderate risk of bias or multiple large observational studies. GRADE defines low quality evidence as evidence where further research is very likely to have an important influence on our confidence in the estimates, or likely to change the estimate.²³ Evidence was rated as low if supported by multiple RCTs of small sample size or high risk of bias or by single observational studies only. GRADE defines very low quality of evidence as evidence where the estimate of the effect is very uncertain.²³ Evidence was rated as very low if supported by single small RCTs, or non-randomised trials or single arm intervention studies. Evidence could be downgraded in the event of other potential biases (such as study limitations, inconsistency of results, imprecision, publication bias²⁴ or conflicts of interest).

RESULTS

Search strategy and study characteristics

The search strategy to identify published systematic reviews identified 1507 abstracts, of which 16 were duplicates and were removed by reference managing software. After title and abstract screening, 1366 abstracts were excluded and the full manuscripts of the remaining 125 were screened. Seventy-nine of these assessed exercise and 10 assessed weight (figure 1).

The search strategy to identify original articles assessing exercise in RMDs identified 4031 abstracts. After removal of 597 duplicates, 3434 titles and abstracts were screened. Of these 223 full manuscripts were screened, of which 157 are included in this review (figure 2). The search

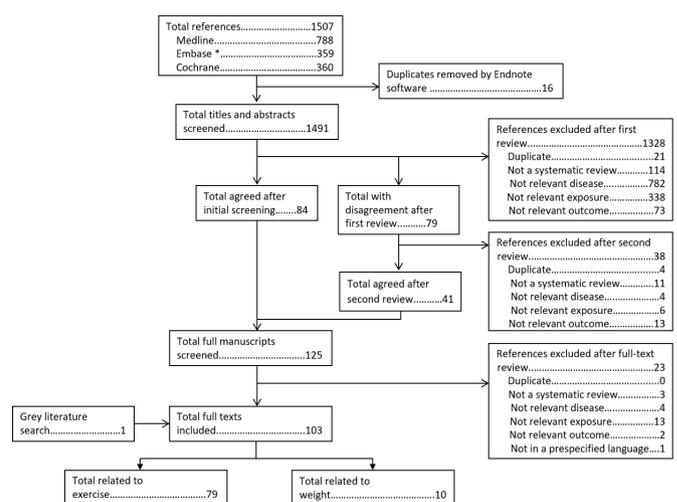


Figure 1 Flow chart of search strategy to identify published systematic reviews and meta-analyses. *EMBASE search excluded journals included in MEDLINE.

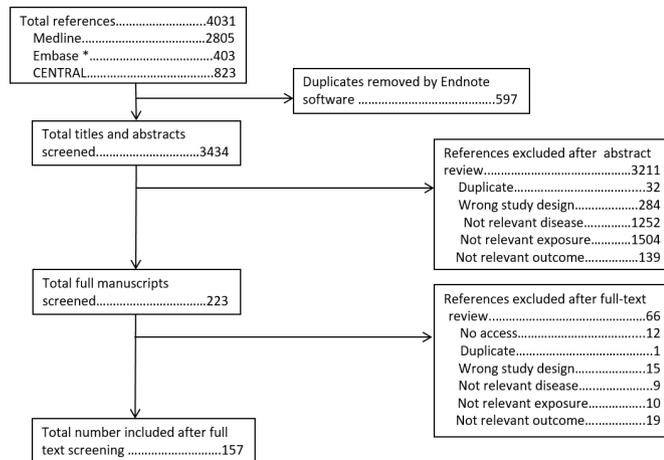


Figure 2 PRISMA flow chart for review of individual studies of exercise. *EMBASE search excluded journals included in MEDLINE. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

strategy to identify original articles assessing weight identified 3973 abstracts. Once duplicates were removed, 3625 abstracts were screened, followed by screening of 304 full manuscripts. In total, 171 studies on weight were included (figure 3). Results are summarised in tables 1 and 2, with additional information on demographics, specific interventions and control groups (typically usual care or wait-list control), and results of meta-analyses provided in online supplemental material.

Exercise

Osteoarthritis

Aerobic exercise

Four meta-analyses of RCTs,^{25–28} four systematic reviews of RCTs^{29–32} and three systematic reviews of observational studies^{33–35} assessed aerobic exercise for OA. Aerobic exercise improved pain^{25–27 30–33} and function^{25 29–32 34} with small-medium effect sizes (pain SMD ranges -0.24 (95% CI -0.50 to 0.02)³⁰ to -0.61 (95% CI -0.75 to

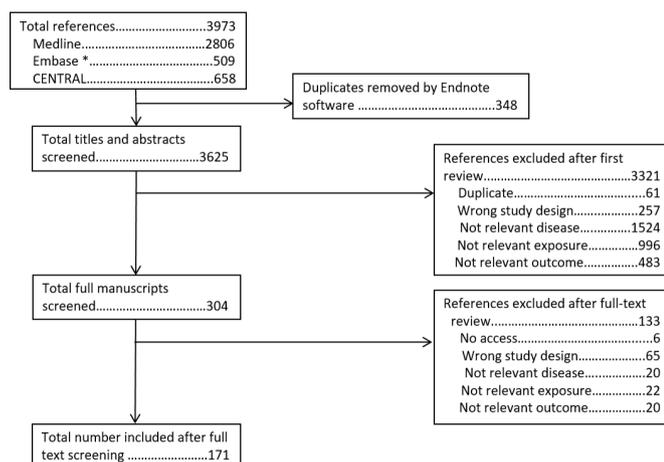


Figure 3 PRISMA flow chart for review of individual studies of weight. *EMBASE search excluded journals included in MEDLINE. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

-0.48)²⁵; function -0.30 (95% CI -1.53 to 0.92)²⁸ to -0.58 (95% CI -0.75 to -0.40)²⁵) as well as one study reporting an association with health-related QoL (HR-QoL).³¹ Another review reported no association with radiographic damage³⁵ (online supplemental tables 6 and 7).

Aquatic exercise

Five meta-analyses of RCTs^{28 36–39} and three systematic reviews of RCTs^{7 32 40} studied aquatic exercise for OA. Small effects on pain^{7 28 32 36 37 39} (SMDs ranging -0.26 (95% CI -0.41 to -0.11)³⁹ to -1.16 (95% CI -3.03 to 0.71)³⁸) function^{7 32 37–39} (SMDs ranging -0.22 (95% CI -0.38 to -0.07)³⁹ to -0.55 (95% CI -0.94 to -0.16)³⁸) and HR-QoL^{37–39} (SMDs ranging -0.21 (95% CI -0.59 to 0.18)³⁸ to -0.25 (95% CI -0.49 to -0.01)³⁷) were reported (online supplemental tables 8 and 9).

Guidelines / recommendations

Two systematic reviews^{41 42} summarised recent guidelines and evidence for OA and exercise, both concluding that exercise is strongly recommended for OA. A third paper⁴³ contained a literature review supporting EULAR recommendations for the non-pharmacological management of OA, also recommending that patients with OA have regular, individualised exercise regimens (online supplemental tables 10 and 11).

High vs low intensity exercise

One Cochrane review⁴⁴ reported that high intensity exercise was more beneficial than low intensity exercise for pain (meta-MD in the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain scale -0.84 (95% CI -1.63 to -0.04)) and function (meta-MD WOMAC function -2.65 (95% CI -5.29 to -0.01)) in OA. A systematic review⁴⁵ identified one prospective study⁴⁶ that reported no exercise or low intensity exercise was associated with deterioration in physical function (online supplemental tables 12 and 13).

Home exercise

One meta-analysis⁴⁷ reported that home exercise interventions were superior to no exercise in terms of pain (SMD -0.46 (95% CI -0.68 to -0.24)) and function (SMD -0.35 (95% CI -0.56 to -0.15)) in OA, but home exercise programmes were inferior to supervised exercise (online supplemental tables 14 and 15).

Land-based exercise

Several articles assessed the efficacy of any type of land-based exercise (as opposed to aquatic) for OA: five meta-analyses of RCTs,^{36 48–51} one systematic review of meta-analyses, reviews and RCTs⁷ and one systematic review of RCTs.⁴⁰ The meta-analyses all reported small effects in favour of land based exercise in terms of pain (SMDs ranging from -0.24 (95% CI -0.42 to -0.06)⁴⁸ to -0.49 (95% CI -0.59 to -0.39)⁵¹) and function (SMDs ranging from -0.34 (95% CI -0.50 to -0.18)⁴⁸ to -0.52 (95% CI -0.64 to -0.39)⁵¹), with the systematic reviews in agreement. One meta-analysis also reported an improvement

Table 1 Summary table of results regarding exercise

Level of evidence	Disease	Effect size			
		None	Small	Medium	Large
Very low	OA				
	RA				
	axSpA				
	Other	<u>SLE</u> Muscle strengthening (disease activity)		<u>PsA</u> Muscle strengthening (function, disease activity)	
Low	OA				Yoga (function)
	RA	Tai chi (pain, function, disease activity); Yoga (disease activity)		Yoga (function)	
	axSpA		Aquatic (pain, function, disease activity)	Aerobic (pain, function)	
	Other	<u>SLE</u> Aerobic (disease activity) <u>SSc</u> Aerobic + muscle strengthening (pain)	<u>SSc</u> Aerobic + muscle strengthening (pain)		
Moderate	OA				
	RA	Aerobic (disease activity); Aerobic + muscle strengthening (disease activity) Muscle strengthening (disease activity)	Aerobic + muscle strengthening (pain) Aquatic (pain, function) Muscle strengthening (pain, function)		
	axSpA			Muscle strengthening (pain, function, disease activity)	
	Other			<u>SLE</u> Aerobic (fatigue)	
High	OA		Aquatic (pain, function, HR-QoL); Exercise therapy (pain, function); Muscle strengthening (pain, function) Tai chi (stiffness, HR-QoL)	Aerobic (pain, function); Land-based (pain, function) Tai chi (pain, function)	
	RA		Aerobic (pain, function); Aerobic + muscle strengthening (function)		
	axSpA			Aerobic + muscle strengthening (pain, function, disease activity)	
	Other				

axSpA, axial spondyloarthritis; HR-QoL, health-related quality of life; OA, osteoarthritis; PsA, psoriatic arthritis; RA, rheumatoid arthritis; SLE, systemic lupus erythematosus; SSc, systemic sclerosis.

in HR-QoL following exercise (SMD 0.28 (95% CI 0.15 to 0.40))⁵¹ (online supplemental tables 16 and 17).

Multidisciplinary interventions

One meta-analysis⁵² and one systematic review⁵³ reported multimodal interventions were superior to exercise only for pain, function and HR-QoL (online supplemental tables 18 and 19).

Muscle strengthening exercise

Nine meta-analyses of RCTs,^{25–28 54–58} four systematic reviews of RCTs,^{29 59 60} and one review of meta-analyses,

reviews and RCTs⁷ assessed muscle strengthening exercise for OA. Small^{26 55 56 58} to medium^{25 27 28} sized effects on pain^{7 59 60} (SMDs ranging from –0.23 (95% CI –0.42 to –0.04)⁵⁵ to –1.19 (95% CI –1.67 to –0.70)⁵⁷), as well as small^{28 56} to medium^{25 57 58} effects on function were reported^{7 59 60} (SMDs ranging from –0.10 (95% CI –0.33 to 0.13)⁵⁵ to –0.60 (95% CI –0.83 to –0.37)²⁵). One meta-analysis reported no effect of muscle strengthening exercise on HR-QoL for hand OA,⁵⁶ whereas a systematic review reported improvements in HR-QoL in knee OA⁵⁹ (online supplemental tables 20 and 21).

Table 2 Summary table of results from observational studies within the weight systematic review

Outcome	RMD							
	OA	RA	SLE	axSpA	PsA	SSc	Gout	
Pain	✓✓✓	✓✓	–	✓	✓	–	–	
Function	✗	✓✓✓	✓	–	✓	–	✗	
Radiographic progression	✗	✓✓†	–	✓	–	–	–	
Disease activity	–	✓✓✓	✗	✓✓	✓✓	–	✓ (serum uric acid, gout attacks)	
Fatigue	–	✓	✗	✓	–	–	–	
Comorbidities	–	✓✓	✓✓	✓	–	–	–	
Other	–	–	–	–	✓(Enthesitis) ✓(Psoriasis score)	–	–	
Mortality	–	✓✓✓*	–	–	–	✓*	–	

Level of evidence of an association between weight and outcome: ✓=very low quality, ✓✓=low quality, ✓✓✓=moderate quality, ✓✓✓✓=high quality, ✗=No evidence of association between weight and outcome from included observational studies, –=No information from included observational studies

This table refers to results where increasing weight is associated with worse scores on outcome measures or higher risk of poor outcomes, other than where noted as follows

*Higher weight associated with lower risk of mortality.

†Higher weight associated with lower radiographic progression in RA.

axSpA, axial spondyloarthritis; OA, osteoarthritis; PsA, psoriatic arthritis; RA, rheumatoid arthritis; RMD, rheumatic and musculoskeletal diseases; SLE, systemic lupus erythematosus; SSc, systemic sclerosis.

Physical exercise therapy

In total, five meta-analyses of RCTs,^{61–65} two systematic reviews of RCTs,^{60 66} and one systematic review of reviews and RCTs⁶⁷ assessed exercise therapy for OA. Small effects for pain^{60 62–64 66} (SMDs ranging from –0.20 (95% CI –0.28 to –0.11)⁶² to –0.71 (95% CI –1.60 to 0.19)⁶⁴) and function were reported^{60 62 63 65 66} (SMDs ranging from –0.07 (95% CI –0.28, 0.15)⁶⁴ to –0.33 (95% CI –0.50 to –0.15)⁶³), and no effect on anxiety (SMD –0.11 (95% CI –0.26 to 0.05)) and depression (SMD –0.16 (95% CI –0.29 to –0.02)).⁶² One meta-analysis reported a medium-sized effect on HR-QoL in knee OA (SMD 0.70 (95% CI 0.20 to 1.20)),⁶¹ but another reported no effect in hip OA (SMD –0.06 (95% CI –0.27 to 0.16))⁶³ (online supplemental tables 22 and 23).

Tai chi

Four meta-analyses of RCTs^{26 68–70} and one systematic review of RCTs⁷¹ assessed tai chi for OA. Medium-sized effects were reported in terms of pain^{26 68–70} (SMDs ranged from –0.45 (95% CI –0.70 to –0.20)⁷⁰ to –0.77 (95% CI –1.13 to –0.41)⁶⁸) and function^{68–70} (SMDs ranged from –0.61 (95% CI –0.85 to –0.37)⁷⁰ to –0.75 (95% CI –0.98 to –0.52)⁶⁸), and small effects on stiffness^{68 70} and HR-QoL^{68 69} (online supplemental tables 24 and 25).

Yoga

One meta-analysis of RCTs,⁷² two systematic reviews of RCTs^{71 73} and one systematic review of RCTs and single arm interventions,⁷⁴ assessed yoga in OA. Three systematic reviews reported benefits of yoga on pain and function.^{71 73 74} The meta-analysis reported a large effect of yoga on function (SMD –1.83 (95% CI –2.09 to –1.57)).⁷²

One systematic review reported inconsistent findings in terms of the effect of yoga on HR-QoL⁷⁴ (online supplemental tables 26 and 27).

OA summary

The majority of systematic reviews and meta-analyses reported medium-sized effects of physical activity on pain and function in OA, including both aerobic and muscle strengthening physical activity. The quality of the evidence was generally moderate to high (table 1). While the majority of studies on OA included people with knee or hip OA, several studies included people with hand OA.^{42 52 55 56 64 73}

Rheumatoid arthritis

Aerobic exercise

One meta-analysis,⁷⁵ three systematic reviews^{76–78} (which highlighted a 2010 meta-analysis,⁷⁹) eight RCTs,^{80–87} four non-randomised studies,^{88–91} one case-control study⁹² and two prospective cohort studies^{93 94} assessing aerobic exercise in RA were included. Aerobic exercise improved pain^{76 77 79 80 82 84 87} (meta-analysis⁷⁹: SMD 0.31 (95% CI 0.06 to 0.55)); and function^{76 79 80 84} (meta-analysis⁷⁹: SMD 0.24 (95% CI 0.10 to 0.38)) in RA with small effect sizes, although some studies reported statistically non-significant results. One meta-analysis and four included RCTs reported no effect of aerobic exercise on disease activity^{79 80 82 83 85} (meta-analysis⁷⁹: SMD 0.08 (95% CI –0.08 to 0.25)), while another reported a weak correlation.⁷⁸ Furthermore, studies reported a small effect on HR-QoL.^{79 81 82 84} Small effects were also reported on fatigue (meta-analysis⁷⁵: SMD –0.31 (95% CI –0.55 to –0.06)), anxiety, depression and self-efficacy^{75 81 82 85} (online supplemental tables 28–31).

Aerobic + muscle strengthening exercise

Twenty-one reports of RCTs,^{95–115} one non-randomised trial,¹¹⁶ and seven single arm studies^{117–123} reported on interventions containing both aerobic and muscle strengthening elements in RA. Small effects were reported for pain^{96 99 101 106 110–112} and function,^{95–100 102 106 108–111 115} with wide heterogeneity between studies potentially due to differences in the interventions and follow-up lengths. No effect was observed for disease activity^{102 106 108 110} and depression.^{97 101} Two RCTs reported a small effect on HR-QoL, which was not statistically significant.^{98 102} One recent RCT reported a medium-sized effect on fatigue,⁹⁶ with two older RCTs reporting no effect^{101 115} (online supplemental tables 32 and 33).

Aquatic exercise

Two systematic reviews,^{77 124} four RCTs^{87 125–127} and one non-randomised trial⁸⁹ studied aquatic exercises for RA. Small-medium effects on pain^{87 124 126} and function^{77 124–127} were reported (online supplemental tables 34–36).

High vs low intensity

Three RCTs^{128–130} and one long-term extension¹³¹ were included, with none reporting significant differences between high and low intensity exercise on pain or function (online supplemental tables 37 and 38).

Home exercise

Two systematic reviews,^{77 132} and five RCTs^{101 133–136} studied home exercise programmes. The reviews concluded that home exercise was beneficial for reducing pain and function.^{77 132} In studies comparing home-based unsupervised physical activity to supervised physical activity, inconsistent results were reported in terms of pain^{101 134 135} and function^{134–136} potentially due to differences in the interventions between studies (online supplemental tables 39–41).

Muscle strengthening exercise

One meta-analysis of hand muscle strengthening exercises,¹³⁷ three systematic reviews (one including a 2012 meta-analysis^{138 77 139 140}) 17 reports of RCTs and long-term extensions,^{128 131 141–155} 1 non-randomised trial¹⁵⁶ and 1 single-arm study¹⁵⁷ assessed muscle strengthening exercise in RA. Small effects from muscle strengthening exercise were reported on pain^{77 137 138 140 141 143 144 153} (meta-analysis¹³⁸: MD pain Visual Analogue Scale -4.13 (95% CI -10.97 to 2.71)). Inconsistent results were reported in terms of function, with several studies reporting improvements in function^{77 137 138 143 148 149 151} (meta-analysis¹³⁸: MD Health Assessment Questionnaire -0.22 (95% CI -0.35 to -0.10)), whereas other RCTs reported no benefit,^{128 144 147 152 153} potentially due to differences in the comparison group where some were given low-intensity exercise or exercise advice. No effect was reported on disease activity^{128 140 143 145 147} and HR-QoL^{142 144 145 147} (online supplemental tables 42–44).

Tai chi

One systematic review (which identified a 2004 review^{158 77}) one RCT,¹⁵⁹ one non-randomised trial¹⁶⁰ and two single-arm studies^{161 162} assessed tai chi for RA. The reviews and RCT reported no benefit in terms of pain,¹⁵⁹ function,^{77 158 159} disease activity^{77 158} or depression¹⁵⁹ (online supplemental tables 45–47).

Yoga

One meta-analysis,⁷² one systematic review,⁷³ three RCTs^{163–165} and two non-randomised trials^{166 167} studied yoga for RA. The meta-analysis reported a large effect of yoga on pain (but included some patients with OA)⁷² as did one RCT,¹⁶⁵ whereas two other RCTs reported no effect, and the systematic review graded the evidence as very low.^{73 163 164} The meta-analysis (only including studies of RA)⁷² and one RCT reported medium-sized effects on function,¹⁶³ whereas another RCT reported no effect.¹⁶⁴ No effect on disease activity was reported by two RCTs.^{163 164} Studies were generally small therefore potentially some findings are due to chance (online supplemental tables 48–50).

RA summary

There was moderate-high quality evidence of a small effect of physical activity on pain and function in RA. Physical activity did not affect disease activity (table 1).

Systemic lupus erythematosus

Aerobic exercise

Two meta-analyses,^{168 169} three systematic reviews,^{170–172} four RCTs^{173–176} and three non-randomised trials^{177–179} assessed aerobic exercise in SLE. One RCT reported lower pain,¹⁷³ whereas another did not¹⁷⁴ although both studies had low sample sizes. No effect of disease activity was reported.^{168 173 174} A medium-sized effect on fatigue was also reported (MD -0.61 [95% CI -1.19 to -0.02]¹⁶⁸; MD -0.52 [95% CI -0.92 to -0.13]¹⁶⁹)^{168 169 171 172 175 176} (online supplemental tables 51–53).

Aerobic & muscle strengthening exercise

One meta-analysis,¹⁶⁸ one systematic review¹⁷¹ and three RCTs^{173 180 181} compared aerobic and muscle strengthening exercise, whereas one RCT¹⁸² and one non-randomised trial¹⁸³ assessed interventions combining both aerobic and muscle strengthening exercises. Aerobic exercise was reported to lead to less fatigue compared with muscle strengthening in two studies,^{168 171} but two other RCTs reported no difference,^{180 181} although again sample sizes were small. No difference was reported in terms of disease activity^{168 173 181} or depression^{168 173 180} (online supplemental tables 54–56).

Muscle strengthening exercise

One RCT compared muscle strengthening exercise to control in SLE,¹⁷³ reporting no effect on disease activity, pain and fatigue, but a medium-sized effect

on depression in favour of muscle strengthening exercise (online supplemental tables 57 and 58).

SLE summary

There is moderate quality evidence of a medium-sized effect of aerobic exercise on fatigue in SLE. There is low-quality evidence that physical activity does not affect disease activity in SLE (table 1).

Axial spondyloarthritis

Aerobic exercise

Two systematic reviews,^{184 185} four RCTs,^{186–189} one single arm study¹⁹⁰ and three prospective cohort studies^{191–193} assessed aerobic exercise in axSpA. One RCT investigating exercising with the aid of a video game console reported a medium-sized effect on pain, function and disease activity,¹⁸⁶ whereas other studies of traditional exercise interventions reported no effect^{184 187–189} (online supplemental tables 59–62).

Aerobic + muscle strengthening exercise

Six meta-analyses,^{194–199} 3 systematic reviews,^{184 185 200} 10 RCTs,^{201–210} 3 non-randomised trials,^{211–213} 5 single arm studies^{214–218} and 1 prospective cohort study²¹⁹ assessed aerobic + muscle strengthening exercise in axSpA. Small effects were reported for pain,^{185 196 197 204 209 210} but with some inconsistency^{200 207 208} (SMDs ranging from -0.22 (95% CI -0.49 to 0.06)¹⁹⁷ to -0.42 (95% CI -0.74 to -0.09),¹⁹⁶ whereas consistent medium-sized improvements in function^{184 194–199 201 203 205 207 210} (SMDs ranging from -0.44 (95% CI -0.79 to -0.09)¹⁹⁹ to -0.72 (-1.03 to -0.40),¹⁹⁴ and disease activity^{184 194–199 201 205 206} (SMDs ranging from -0.47 (95% CI -0.84 to -0.09)¹⁹⁶ to -0.90 (-1.52 to -0.27)¹⁹⁴ were reported. Medium-sized effects on fatigue^{201 202} and spinal mobility^{195 198 199 205} were also reported (online supplemental tables 63–66).

Aquatic exercise

Three systematic reviews^{184 200 220} and two RCTs^{221 222} assessing aquatic exercise for axSpA were included. Small, inconsistent effects were reported in terms of pain,^{184 220–222} function^{184 200 220–222} and disease activity^{184 220–222} and no effect on spinal mobility^{184 221 222} (online supplemental tables 67–69).

Home-based exercise

One meta-analysis,¹⁹⁷ one systematic review,¹⁸⁵ eight RCTs,^{186 189 203 207 210 223–225} five non-randomised trials^{212 226–229} and one single arm study²¹⁷ assessed home-based exercise. Compared with control, home exercise had a medium-sized effect on pain,^{186 197 210 224} function,^{186 189 197 210 223–225} disease activity^{186 197 223 224} and HR-QoL.^{186 224} However, several studies found that group-based exercise was more effective than home-based exercise in terms of function^{203 207} and disease activity²⁰³ (online supplemental tables 70–72).

Muscle strengthening exercise

Eight RCTs (and two long-term follow-ups),^{223 225 230–237} three non-randomised trials^{226–228} and three single arm studies^{238–240} assessed muscle strengthening exercise. Medium-sized effects of muscle strengthening exercise were reported in terms of pain,^{225 231–233 235} function^{223 225 230 232–235} and disease activity^{223 230 232–235} (online supplemental tables 73 and 74).

AxSpA summary

There is high-quality evidence of a medium-sized effect of aerobic + muscle strengthening exercise in axSpA. Muscle strengthening exercise results in larger and more consistent effects on pain, function and disease activity compared with aerobic exercise (table 1).

Psoriatic arthritis

Muscle strengthening exercise

One RCT²⁴¹ and one single arm study²⁴² assessed muscle strengthening exercise in PsA. The RCT reported better function and disease activity at 12 weeks compared with the control arm²⁴¹ (online supplemental tables 75 and 76).

PsA Summary

There is little evidence of the effect of physical activity in PsA.

Systemic sclerosis

Aerobic exercise

One single arm study²⁴³ reported improvements in function between baseline and 4 months after the intervention (online supplemental tables 77 and 78).

Aerobic + muscle strengthening exercise

One systematic review,²⁴⁴ two RCTs^{245 246} and one single arm study²⁴⁷ assessed aerobic plus muscle strengthening interventions for SSc, reporting a small effect on function^{245 246} but no effect on pain²⁴⁶ (online supplemental tables 79–81).

Aquatic exercise

One RCT,²⁴⁸ which only reported data on the intervention group, showed improvements in function from baseline to 18 weeks follow-up (online supplemental tables 82 and 83).

Muscle strengthening exercise

One RCT,²⁴⁹ one non-randomised trial²⁵⁰ and three single arm studies^{251–253} assessed muscle strengthening exercise in SSc. The RCT reported a medium-sized effect on function²⁴⁹ and the non-randomised study reported better outcomes in terms of pain and function in the exercise arm²⁵⁰ (online supplemental tables 84 and 85).

SSc summary

There is very-low-quality evidence of a medium effect of physical activity on function in SSc (table 1).

Gout

Aerobic exercise

One case-control study²⁵⁴ reported that performing regular exercise ≥ 150 min per week was associated with reduced odds of tophus in gout (online supplemental tables 86 and 87).

Yoga

One RCT compared yoga to blood-letting in gout,²⁵⁵ reporting benefits of yoga in terms of pain and serum uric acid (online supplemental tables 88 and 89).

Gout summary

There is little research on the effect of physical activity in gout.

Body weight and weight reduction

Osteoarthritis

Two meta-analyses,^{26 33} 5 systematic reviews,^{32 34 35 43 45} 21 reports describing RCTs and long-term follow-up studies,^{256–276} 2 non-randomised trials^{277 278} and 6 single-arm intervention studies assessing weight-loss interventions,^{279–284} as well as 44 observational studies^{285–328} assessing the association between body weight and outcomes in OA were identified. From studies assessing weight-loss interventions, small effects on pain,^{26 32 43 265–267 270 275} function,^{259 265–268 270 272 273} stiffness^{256 266 273} and walking tests,^{260 265 272 276} but no effect on HR-QoL^{260 269} or patient global assessment^{260 269} were reported. In observational studies, higher body weight was associated with higher pain^{33 291 292 299 300 302 307} but not with worse function^{45 287 297 303 319} or radiographic progression^{35 294 301 306} (online supplemental tables 90–115).

Rheumatoid arthritis

Three meta-analyses^{329–331} and 61 observational studies^{92 332–391} assessed the relationship between body weight and outcomes in RA. Higher weight was associated with worse pain,^{329 354 361 362 380} function,^{329 336 344 362} disease activity,^{329 330 336 338 339 342 344 347 357 361–363 366 384 389} and fatigue,³⁵¹ as well as more comorbidities.^{331 355 360 365 374 390} Higher baseline weight was associated with lower risk of death.^{335 367 378 379} However, high rates of weight loss were associated with increased mortality risk.^{335 340 356 381} Higher weight was associated with lower radiographic progression^{337 341 346 347 368 371 375 376} (online supplemental tables 116–132).

Systemic lupus erythematosus

Eight prospective studies were identified assessing the relationship between body weight and outcomes in SLE.^{392–399} Higher weight was associated with worse function,³⁹⁴ comorbidity,^{396 398 399} employment status³⁹⁴ and mental health,³⁹² but no associations between weight and disease activity³⁹⁵ or fatigue³⁹⁵ were reported (online supplemental tables 133–139).

Axial spondyloarthritis

Thirteen observational studies were identified assessing the relationship between body weight and outcomes in axSpA.^{192 359 400–410} Higher weight was associated with worse pain,⁴¹⁰ disease activity,^{405 410} fatigue,⁴⁰⁵ radiographic progression,^{401 403} comorbidity^{359 404} and lower odds of meeting response criteria.^{405 409} One unadjusted analysis reported people with higher weight were more likely to discontinue anti-tumour necrosis factor treatment,⁴⁰⁶ but another study adjusting for confounders reported no association⁴⁰⁵ (online supplemental tables 140–149).

Psoriatic arthritis

One meta-analysis,³³⁰ one RCT,⁴¹¹ one single-arm study⁴¹² and seven observational studies^{413–419} were identified assessing the relationship between weight and outcomes in PsA. Higher weight was associated with worse pain,⁴¹⁵ function,⁴¹⁵ disease activity,^{330 414–417} joint counts,⁴¹⁵ enthesitis occurrence⁴¹³ and psoriasis score.⁴¹⁵ Interventional studies reported improvements in pain,^{411 412} function,^{411 412} patient global assessment,^{411 412} and reductions in disease activity^{411 412} and C-reactive protein^{411 412} following weight loss (online supplemental tables 150–170).

Systemic sclerosis

Two observational studies reported that higher weight was associated with a lower risk of mortality in SSc^{420 421} (online supplemental tables 171 and 172).

Gout

One systematic review,⁴²² one single-arm study⁴²³ and five observational studies^{424–428} were identified assessing the relationship between weight and outcomes in gout. One observational study reported no association between weight and function.⁴²⁸ Weight loss was associated with improvements in serum uric acid level,^{422 423 425} and less frequent gout attacks.^{422–425} Higher weight was associated with renal failure in one study⁴²⁶ but not another.⁴²⁸ (online supplemental tables 173–180).

DISCUSSION

These three systematic reviews summarise the current evidence regarding the effects of physical activity and body weight on disease outcomes of people with seven RMDs. The data from over 400 published reviews and original articles suggests there are benefits of exercising for a range of outcomes important to people with RMDs, and also indicate an association between heavier body weight and worse outcomes, although differences were noted across RMDs. There was moderate-to-high-quality evidence that exercise interventions resulted in less pain and better function in RMDs, and exercise was also associated with reductions in disease activity in axSpA. The size of the effect of exercise varied between RMDs. For instance, there were medium-sized effects demonstrated in people with axSpA and only small effects in those with

RA. There was moderate-quality evidence that heavier body weight was associated with poorer outcomes, including pain, function and disease activity, with relatively consistent results across the seven RMDs. However, the amount of available evidence varied considerably between RMDs, with the majority of studies focusing on OA, RA, axSpA and to a lesser extent SLE, with only a few studies available focusing on PsA, SSc and gout.

The majority of studies of exercise across the RMDs focused on aerobic and muscle strengthening exercise. Both appeared to improve outcomes in the seven RMDs included in this review, and when combined they seemed to produce stronger effects, although relatively few studies compared aerobic plus muscle strengthening exercise to either form of exercise individually.¹⁷³ A few studies indicated that supervised exercise was marginally more effective than unsupervised home-based exercise,^{47 134 203} although this should not deter individuals who do not wish to attend exercise classes from performing home-based exercise. Overall, the current evidence base indicates that exercising results in better outcomes in people with RMDs, when compared with groups assigned to control groups with no exercise intervention. People with RMDs should be encouraged by their health professionals to start exercising if they currently perform no exercise, or maintain their exercise if they already perform a sufficient amount of exercise. Health professionals should also recognise that there are potentially large barriers to initiating and continuing to exercise for people with RMDs, including time, resources and lack of motivation, as well as disease specific barriers.^{429–431}

Heavier body weight was consistently associated with poorer outcomes, including pain, function, disease activity, fatigue and comorbidities. The included studies evaluating weight-loss interventions typically reported improved outcomes in the weight-loss groups compared with controls.^{260 265 411} Additionally, multiple observational studies have reported an association between heavier baseline weight and worse disease outcomes. While these observational studies typically have longer follow-up compared with RCTs, causality between heavier body weight and worse outcomes is difficult to establish, given the complex interrelated associations between heavy weight and other potential sociodemographic and biological factors that could be influencing outcomes.^{432 433} Furthermore, the majority of research focused on OA and RA, with few research studies published on the other RMDs. Despite this, given the deleterious effect of heavier weight on other outcomes (eg, cardiovascular disease¹³ and type 2 diabetes¹⁴) and the association between weight and poor outcomes in RMDs, people with RMDs should be encouraged to attain and maintain a healthy weight (what consists a healthy weight will be person-specific and should be decided in consultation between the person with an RMD and their health professional).

This review has several limitations. While the large scope and high number of studies included means that a large proportion of the literature has been surveyed, due to the breadth of the research questions, some studies may have been missed. However, the extensive search strategies which were implemented in several databases should mean that these missing studies comprise a low proportion of the total evidence base. Due to the large number of studies, data extraction and risk of bias assessment were not performed in duplicate. Furthermore, due to the nature of the method of identifying studies, some selection bias could be influencing the results, particularly in the body weight systematic review. Many studies will assess multiple factors influencing progression of outcomes, and will often only report the significant associations in their abstracts. As our search strategy identified studies reporting that they studied the association between weight and outcomes in their abstracts, this potentially means we missed studies that assessed the association, found no relationship, and therefore did not report they had assessed weight in their abstract. The majority of studies on exercise were RCTs, with strict inclusion criteria, meaning the samples in these studies were often highly selected, thus reducing generalisability. The majority of studies on weight were longitudinal observational studies. While these studies typically had longer follow-up periods than the few interventional studies included, there is the possibility of differential attrition leading to biased results. For instance, those with higher weight may be more likely to have worse outcomes, which could lead them to leave the study before these outcomes are assessed. Lastly, as the evidence within this review was used to formulate the taskforce's recommendations, an update was not deemed appropriate. However, this means that some relevant papers have been published in the interim between implementing the search strategy and publishing this paper which are not included.^{434 435}

In conclusion, these reviews inform the 2021 EULAR recommendations which advise people with RMDs to perform sufficient amounts of exercise, given the beneficial effects of exercise on numerous outcomes. Furthermore, the 2021 EULAR recommendations also advise people with RMDs to maintain a healthy weight, given the association between heavier weight and poor outcomes, as detailed in this review.

Author affiliations

¹Centre for Epidemiology Versus Arthritis, Faculty of Biology, Medicine and Health, The University of Manchester, Manchester, UK

²EA 4360 Apemac, Université de Lorraine, Nancy, France

³Center on Aging and Mobility, University of Zurich, Zurich, Switzerland

⁴Unit of Immunology, Rheumatology, Allergy and Rare Diseases, IRCCS San Raffaele Hospital and Vita-Salute San Raffaele University, Milan, Italy

⁵Department of Internal Medicine and Rheumatology, "Sf. Maria" Hospital, "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania

⁶Department of Aging Medicine and Aging Research, University Hospital Zurich and University of Zurich, Zurich, Switzerland

- ⁷University Clinic for Aging Medicine, City Hospital Zurich - Waid, Zurich, Switzerland
- ⁸Department of Internal Medicine, Division of Rheumatology, Maastricht University Medical Center, Maastricht, The Netherlands
- ⁹Care and Public Health Research Institute (CAPHRI), Maastricht University, Maastricht, The Netherlands
- ¹⁰Centre for Rheumatic Diseases, King's College London, London, UK
- ¹¹Department of Clinical Medicine, Aarhus University, Aarhus, Denmark
- ¹²Department of Rheumatology, Aarhus University Hospital, Aarhus, Denmark
- ¹³Centre for Public Health, Department of Social and Preventive Medicine, Medical University of Vienna, Vienna, Austria
- ¹⁴Social Insurance Fund for Public Service, Railway and Mining Industries, Sitzenberg-Reidling, Austria
- ¹⁵Karl-Landsteiner Institute for Health Promotion Research, Sitzenberg-Reidling, Austria
- ¹⁶National Advisory Unit for Rehabilitation in Rheumatology, Division of Rheumatology and Research, Diakonhjemmet Hospital, Oslo, Norway
- ¹⁷Area of Immunology, Department of Functional Biology, Universidad de Oviedo, Oviedo, Spain
- ¹⁸Department of Metabolism, Instituto de Investigación Sanitaria del Principado de Asturias (ISPA), Oviedo, Spain
- ¹⁹Rheumatology Department, Hospital Universitari Son Espases, Palma de Mallorca, Spain
- ²⁰Section for Outcomes Research, Center for Medical Statistics, Informatics, and Intelligent Systems, Medical University of Vienna, Vienna, Austria
- ²¹Ludwig Boltzmann Institute for Arthritis and Rehabilitation, Vienna, Austria
- ²²MRC Versus Arthritis Centre for Musculoskeletal Health and Work, University of Southampton, Southampton, UK
- ²³NVLE Dutch Patient Organization for Systemic Autoimmune Diseases, Utrecht, The Netherlands
- ²⁴Institute of Rheumatology, University of Belgrade School of Medicine, Belgrade, Serbia
- ²⁵Department of Internal Medicine, University of East Sarajevo Faculty of Medicine Foča, Republika Srpska, Bosnia and Herzegovina
- ²⁶Inserm, CHRU Nancy, CIC-1433 Epidémiologie Clinique, Université de Lorraine, Nancy, France
- ²⁷NIHR Manchester Biomedical Research Centre, Manchester University NHS Foundation Trust, Manchester Academic Health Science Centre, Manchester, UK

Twitter James M Gwinnutt @james_gwinnutt

Contributors Study concept and design: JMG, MW, JR-C, GC, FG and SMMV; Acquisition of data: JMG, MW, JR-C, GC and SMMV; Analysis and interpretation of data: JMG, MW, JR-C, ABa, HB-F, ABo, GC, SdS, AdT, TED, RHM, PP, LS-F, TAS, KW-B, JW, MZ-S, FG and SMMV; Review of manuscript: JMG, MW, JR-C, ABa, HB-F, ABo, GC, SdS, AdT, TED, RHM, PP, LS-F, TAS, KW-B, JW, MZ-S, FG and SMMV; Guarantor: SMMV.

Funding This work was funded by the European League Against Rheumatism. SMMV and JMG are supported by Versus Arthritis (grant number 21755) and the NIHR Manchester Biomedical Research Centre. The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR or the Department of Health.

Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval This study does not involve human participants.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data sharing not applicable as no datasets generated and/or analysed for this study.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution 4.0 Unported (CC BY 4.0) license, which permits others to copy, redistribute, remix, transform and build upon this work for any purpose, provided the original work is properly cited, a link to the licence is given, and indication of whether changes were made. See: <https://creativecommons.org/licenses/by/4.0/>.

ORCID iDs

James M Gwinnutt <http://orcid.org/0000-0002-1435-8797>
 Maud Wiecezorek <http://orcid.org/0000-0002-4528-9923>
 Giulio Cavalli <http://orcid.org/0000-0001-8728-3004>
 Annelies Boonen <http://orcid.org/0000-0003-0682-9533>

- Annette de Thurah <http://orcid.org/0000-0003-0103-4328>
 Rikke Helene Moe <http://orcid.org/0000-0001-7601-5346>
 Javier Rodríguez-Carrio <http://orcid.org/0000-0002-0011-5102>
 Tanja Stamm <http://orcid.org/0000-0003-3073-7284>
 Mirjana I Zlatković-Švenda <http://orcid.org/0000-0002-7123-140X>
 Francis Guillemin <http://orcid.org/0000-0002-9860-7024>

REFERENCES

- Smolen JS, Aletaha D, Barton A, *et al*. Rheumatoid arthritis. *Nat Rev Dis Primers* 2018;4:18001.
- Martel-Pelletier J, Barr AJ, Cicuttini FM, *et al*. Osteoarthritis. *Nat Rev Dis Primers* 2016;2:16072.
- Kaul A, Gordon C, Crow MK, *et al*. Systemic lupus erythematosus. *Nat Rev Dis Primers* 2016;2:16039.
- GBD 2019 Diseases and Injuries Collaborators. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the global burden of disease study 2019. *Lancet* 2020;396:1204–22.
- Singh JA, Christensen R, Wells GA, *et al*. Biologics for rheumatoid arthritis: an overview of Cochrane reviews. *Cochrane Database Syst Rev* 2009;4:CD007848.
- Fanouriakis A, Kostopoulou M, Alunno A, *et al*. 2019 update of the EULAR recommendations for the management of systemic lupus erythematosus. *Ann Rheum Dis* 2019;78:736–45.
- McAlindon TE, Bannuru RR, Sullivan MC, *et al*. OARSI guidelines for the non-surgical management of knee osteoarthritis. *Osteoarthritis Cartilage* 2014;22:363.
- Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep* 1985;100:126–31.
- U.S. Department of Health and Human Services. *Physical activity guidelines for Americans*. 2nd edn. Washington, DC, 2018.
- World Health Organisation. *Global recommendations on physical activity for health*, 2010.
- Rausch Osthoff A-K, Niedermann K, Braun J, *et al*. 2018 EULAR recommendations for physical activity in people with inflammatory arthritis and osteoarthritis. *Ann Rheum Dis* 2018;77:1251–60.
- Rausch Osthoff A-K, Juhl CB, Knittle K, *et al*. Effects of exercise and physical activity promotion: meta-analysis Informing the 2018 EULAR recommendations for physical activity in people with rheumatoid arthritis, spondyloarthritis and hip/knee osteoarthritis. *RMD Open* 2018;4:e000713.
- Afshin A, Forouzanfar MH, GBD 2015 Obesity Collaborators, *et al*. Health effects of overweight and obesity in 195 countries over 25 years. *N Engl J Med* 2017;377:13–27.
- Abdullah A, Peeters A, de Courten M, *et al*. The magnitude of association between overweight and obesity and the risk of diabetes: a meta-analysis of prospective cohort studies. *Diabetes Res Clin Pract* 2010;89:309–19.
- van der Heijde D, Aletaha D, Carmona L, *et al*. 2014 update of the EULAR standardised operating procedures for EULAR-endorsed recommendations. *Ann Rheum Dis* 2015;74:8–13.
- Moher D, Liberati A, Tetzlaff J, *et al*. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* 2009;6:e1000097.
- Shea BJ, Reeves BC, Wells G, *et al*. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. *BMJ* 2017;358:j4008.
- Higgins JPT, Altman DG, Gøtzsche PC, *et al*. The Cochrane collaboration's tool for assessing risk of bias in randomised trials. *BMJ* 2011;343:d5928.
- Soboczenski F, Trikalinos TA, Kuiper J, *et al*. Machine learning to help researchers evaluate biases in clinical trials: a prospective, randomized user study. *BMC Med Inform Decis Mak* 2019;19:96.
- Hayden JA, van der Windt DA, Cartwright JL, *et al*. Assessing bias in studies of prognostic factors. *Ann Intern Med* 2013;158:280–6.
- Wan X, Wang W, Liu J, *et al*. Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. *BMC Med Res Methodol* 2014;14:135.
- Cohen J. *Statistical power analysis for the behavioral sciences*. 2nd ed. Hillsdale, NJ: Erlbaum, 1988.
- Guyatt GH, Oxman AD, Vist GE, *et al*. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ* 2008;336:924–6.
- Guyatt GH, Oxman AD, Kunz R, *et al*. What is "quality of evidence" and why is it important to clinicians? *BMJ* 2008;336:995–8.
- Juhl C, Christensen R, Roos EM, *et al*. Impact of exercise type and dose on pain and disability in knee osteoarthritis: a systematic

- review and meta-regression analysis of randomized controlled trials. *Arthritis Rheumatol* 2014;66:622–36.
- 26 Corbett MS, Rice SJC, Madurasinghe V, *et al.* Acupuncture and other physical treatments for the relief of pain due to osteoarthritis of the knee: network meta-analysis. *Osteoarthritis Cartilage* 2013;21:1290–8.
 - 27 Tanaka R, Ozawa J, Kito N, *et al.* Efficacy of strengthening or aerobic exercise on pain relief in people with knee osteoarthritis: a systematic review and meta-analysis of randomized controlled trials. *Clin Rehabil* 2013;27:1059–71.
 - 28 Uthman OA, van der Windt DA, Jordan JL, *et al.* Exercise for lower limb osteoarthritis: systematic review incorporating trial sequential analysis and network meta-analysis. *BMJ* 2013;347:f5555.
 - 29 Wijnen A, Bouma SE, Seeber GH, *et al.* The therapeutic validity and effectiveness of physiotherapeutic exercise following total hip arthroplasty for osteoarthritis: a systematic review. *PLoS One* 2018;13:e0194517.
 - 30 Alrushud AS, Rushton AB, Kanavaki AM, *et al.* Effect of physical activity and dietary restriction interventions on weight loss and the musculoskeletal function of overweight and obese older adults with knee osteoarthritis: a systematic review and mixed method data synthesis. *BMJ Open* 2017;7:e014537.
 - 31 Brosseau L, Taki J, Desjardins B, *et al.* The Ottawa panel clinical practice guidelines for the management of knee osteoarthritis. Part three: aerobic exercise programs. *Clin Rehabil* 2017;31:612–24.
 - 32 Quintrec J-LL, Verlhac B, Cadet C, *et al.* Physical exercise and weight loss for hip and knee osteoarthritis in very old patients: a systematic review of the literature. *Open Rheumatol J* 2014;8:89–95.
 - 33 Pozzobon D, Ferreira PH, Blyth FM, *et al.* Can obesity and physical activity predict outcomes of elective knee or hip surgery due to osteoarthritis? A meta-analysis of cohort studies. *BMJ Open* 2018;8:e017689.
 - 34 de Rooij M, van der Leeden M, Heymans MW, *et al.* Prognosis of pain and physical functioning in patients with knee osteoarthritis: a systematic review and meta-analysis. *Arthritis Care Res* 2016;68:481–92.
 - 35 Bastick AN, Belo JN, Runhaar J, *et al.* What are the prognostic factors for radiographic progression of knee osteoarthritis? A meta-analysis. *Clin Orthop Relat Res* 2015;473:2969–89.
 - 36 Beumer L, Wong J, Warden SJ, *et al.* Effects of exercise and manual therapy on pain associated with hip osteoarthritis: a systematic review and meta-analysis. *Br J Sports Med* 2016;50:458–63.
 - 37 Bartels EM, Juhl CB, Christensen R, *et al.* Aquatic exercise for the treatment of knee and hip osteoarthritis. *Cochrane Database Syst Rev* 2016;3:CD005523.
 - 38 Lu M, Su Y, Zhang Y, *et al.* Effectiveness of aquatic exercise for treatment of knee osteoarthritis: systematic review and meta-analysis. *Z Rheumatol* 2015;74:543–52.
 - 39 Waller B, Ogonowska-Slodownik A, Vitor M, *et al.* Effect of therapeutic aquatic exercise on symptoms and function associated with lower limb osteoarthritis: systematic review with meta-analysis. *Phys Ther* 2014;94:1383–95.
 - 40 Romeo A, Parazza S, Boschi M, *et al.* Manual therapy and therapeutic exercise in the treatment of osteoarthritis of the hip: a systematic review. *Reumatismo* 2013;65:63–74.
 - 41 Gay C, Chabaud A, Guilley E, *et al.* Educating patients about the benefits of physical activity and exercise for their hip and knee osteoarthritis. Systematic literature review. *Ann Phys Rehabil Med* 2016;59:174–83.
 - 42 Nelson AE, Allen KD, Golightly YM, *et al.* A systematic review of recommendations and guidelines for the management of osteoarthritis: the chronic osteoarthritis management initiative of the U.S. bone and joint initiative. *Semin Arthritis Rheum* 2014;43:701–12.
 - 43 Fernandes L, Hagen KB, Bijlsma JWW, *et al.* EULAR recommendations for the non-pharmacological core management of hip and knee osteoarthritis. *Ann Rheum Dis* 2013;72:1125–35.
 - 44 Regnaud J-P, Lefevre-Colau M-M, Trinquart L, *et al.* High-intensity versus low-intensity physical activity or exercise in people with hip or knee osteoarthritis. *Cochrane Database Syst Rev* 2015:CD010203.
 - 45 de Rooij M, van der Leeden M, Heymans MW, *et al.* Course and predictors of pain and physical functioning in patients with hip osteoarthritis: systematic review and meta-analysis. *J Rehabil Med* 2016;48:245–52.
 - 46 Juhakoski R, Malmivaara A, Lakka TA, *et al.* Determinants of pain and functioning in hip osteoarthritis - a two-year prospective study. *Clin Rehabil* 2013;27:281–7.
 - 47 Anwer S, Alghadir A, Brismée J-M. Effect of home exercise program in patients with knee osteoarthritis: a systematic review and meta-analysis. *J Geriatr Phys Ther* 2016;39:38–48.
 - 48 Moseng T, Dagfinrud H, Smedslund G, *et al.* The importance of dose in land-based supervised exercise for people with hip osteoarthritis. A systematic review and meta-analysis. *Osteoarthritis Cartilage* 2017;25:1563–76.
 - 49 Fernandopulle S, Perry M, Manlapaz D, *et al.* Effect of Land-Based generic physical activity interventions on pain, physical function, and physical performance in hip and knee osteoarthritis: a systematic review and meta-analysis. *Am J Phys Med Rehabil* 2017;96:773–92.
 - 50 Henriksen M, Hansen JB, Klokke L, *et al.* Comparable effects of exercise and analgesics for pain secondary to knee osteoarthritis: a meta-analysis of trials included in Cochrane systematic reviews. *J Comp Eff Res* 2016;5:417–31.
 - 51 Fransen M, McConnell S, Harmer AR, *et al.* Exercise for osteoarthritis of the knee. *Cochrane Database Syst Rev* 2015;1:CD004376.
 - 52 Aebischer B, Elsig S, Taeymans J. Effectiveness of physical and occupational therapy on pain, function and quality of life in patients with trapeziometacarpal osteoarthritis - A systematic review and meta-analysis. *Hand Ther* 2016;21:5–15.
 - 53 Finney A, Healey E, Jordan JL, *et al.* Multidisciplinary approaches to managing osteoarthritis in multiple joint sites: a systematic review. *BMC Musculoskelet Disord* 2016;17:266.
 - 54 Bartholdy C, Juhl C, Christensen R, *et al.* The role of muscle strengthening in exercise therapy for knee osteoarthritis: a systematic review and meta-regression analysis of randomized trials. *Semin Arthritis Rheum* 2017;47:9–21.
 - 55 Magni NE, McNair PJ, Rice DA. The effects of resistance training on muscle strength, joint pain, and hand function in individuals with hand osteoarthritis: a systematic review and meta-analysis. *Arthritis Res Ther* 2017;19:131.
 - 56 Østerås N, Kjekken I, Smedslund G, *et al.* Exercise for hand osteoarthritis. *Cochrane Database Syst Rev* 2017;1:CD010388.
 - 57 Coudeyre E, Jegu AG, Giustanini M, *et al.* Isokinetic muscle strengthening for knee osteoarthritis: a systematic review of randomized controlled trials with meta-analysis. *Ann Phys Rehabil Med* 2016;59:207–15.
 - 58 Li Y, Su Y, Chen S, *et al.* The effects of resistance exercise in patients with knee osteoarthritis: a systematic review and meta-analysis. *Clin Rehabil* 2016;30:947–59.
 - 59 Brosseau L, Taki J, Desjardins B, *et al.* The Ottawa panel clinical practice guidelines for the management of knee osteoarthritis. Part two: strengthening exercise programs. *Clin Rehabil* 2017;31:596–611.
 - 60 Brosseau L, Wells GA, Pugh AG, *et al.* Ottawa panel evidence-based clinical practice guidelines for therapeutic exercise in the management of hip osteoarthritis. *Clin Rehabil* 2016;30:935–46.
 - 61 Briani RV, Ferreira AS, Pazzinatto MF, *et al.* What interventions can improve quality of life or psychosocial factors of individuals with knee osteoarthritis? A systematic review with meta-analysis of primary outcomes from randomised controlled trials. *Br J Sports Med* 2018;52:1031–8.
 - 62 Hurley M, Dickson K, Hallett R, *et al.* Exercise interventions and patient beliefs for people with hip, knee or hip and knee osteoarthritis: a mixed methods review. *Cochrane Database Syst Rev* 2018;4:CD010842.
 - 63 Sampath KK, Mani R, Miyamori T, *et al.* The effects of manual therapy or exercise therapy or both in people with hip osteoarthritis: a systematic review and meta-analysis. *Clin Rehabil* 2016;30:1141–55.
 - 64 Bertozzi L, Valdes K, Vanti C, *et al.* Investigation of the effect of conservative interventions in thumb carpometacarpal osteoarthritis: systematic review and meta-analysis. *Disabil Rehabil* 2015;37:2025–43.
 - 65 Desveaux L, Beauchamp M, Goldstein R, *et al.* Community-based exercise programs as a strategy to optimize function in chronic disease: a systematic review. *Med Care* 2014;52:216–26.
 - 66 Ferreira GE, Robinson CC, Wiebusch M, *et al.* The effect of exercise therapy on knee adduction moment in individuals with knee osteoarthritis: a systematic review. *Clin Biomech* 2015;30:521–7.
 - 67 Fehring TK, Fehring K, Odum SM, *et al.* Physical therapy mandates by Medicare administrative contractors: effective or wasteful? *J Arthroplasty* 2013;28:1459–62.
 - 68 Zhang Y, Huang L, Su Y, *et al.* The effects of traditional Chinese exercise in treating knee osteoarthritis: a systematic review and meta-analysis. *PLoS One* 2017;12:e0170237.

- 69 Chen Y-W, Hunt MA, Campbell KL, *et al.* The effect of Tai Chi on four chronic conditions-cancer, osteoarthritis, heart failure and chronic obstructive pulmonary disease: a systematic review and meta-analyses. *Br J Sports Med* 2016;50:397-407.
- 70 Yan J-H, Gu W-J, Sun J, *et al.* Efficacy of Tai Chi on pain, stiffness and function in patients with osteoarthritis: a meta-analysis. *PLoS One* 2013;8:e61672.
- 71 Brosseau L, Taki J, Desjardins B, *et al.* The Ottawa panel clinical practice guidelines for the management of knee osteoarthritis. Part one: introduction, and mind-body exercise programs. *Clin Rehabil* 2017;31:582-95.
- 72 Wang Y, Lu S, Wang R, *et al.* Integrative effect of yoga practice in patients with knee arthritis: a PRISMA-compliant meta-analysis. *Medicine* 2018;97:e11742.
- 73 Cramer H, Lauche R, Langhorst J, *et al.* Yoga for rheumatic diseases: a systematic review. *Rheumatology* 2013;52:2025-30.
- 74 Kan L, Zhang J, Yang Y, *et al.* The effects of yoga on pain, mobility, and quality of life in patients with knee osteoarthritis: a systematic review. *Evid Based Complement Alternat Med* 2016;2016:6016532.
- 75 Rongen-van Dartel SAA, Repping-Wuts H, Flendrie M, *et al.* Effect of aerobic exercise training on fatigue in rheumatoid arthritis: a meta-analysis. *Arthritis Care Res* 2015;67:1054-62.
- 76 Hernández-Hernández MV, Díaz-González F. Role of physical activity in the management and assessment of rheumatoid arthritis patients. *Reumatol Clin* 2017;13:214-20.
- 77 Siegel P, Tencza M, Apodaca B, *et al.* Effectiveness of occupational therapy interventions for adults with rheumatoid arthritis: a systematic review. *Am J Occup Ther* 2017;71:7101180050.
- 78 Larkin L, Kennedy N. Correlates of physical activity in adults with rheumatoid arthritis: a systematic review. *J Phys Act Health* 2014;11:1248-61.
- 79 Baillet A, Zeboulon N, Gossec L, *et al.* Efficacy of cardiorespiratory aerobic exercise in rheumatoid arthritis: meta-analysis of randomized controlled trials. *Arthritis Care Res* 2010;62:984-92.
- 80 Katz P, Margaretten M, Gregorich S, *et al.* Physical activity to reduce fatigue in rheumatoid arthritis: a randomized controlled trial. *Arthritis Care Res* 2018;70:1-10.
- 81 Baxter SV, Hale LA, Stebbings S, *et al.* Walking is a feasible physical activity for people with rheumatoid arthritis: a feasibility randomized controlled trial. *Musculoskeletal Care* 2016;14:47-56.
- 82 Feldthusen C, Dean E, Forsblad-d'Elia H, *et al.* Effects of Person-Centered physical therapy on Fatigue-Related variables in persons with rheumatoid arthritis: a randomized controlled trial. *Arch Phys Med Rehabil* 2016;97:26-36.
- 83 Sjöquist ES, Brodin N, Lampa J, *et al.* Physical activity coaching of patients with rheumatoid arthritis in everyday practice: a long-term follow-up. *Musculoskeletal Care* 2011;9:75-85.
- 84 Brodin N, Eurenien E, Jensen I, *et al.* Coaching patients with early rheumatoid arthritis to healthy physical activity: a multicenter, randomized, controlled study. *Arthritis Rheum* 2008;59:325-31.
- 85 Li LC, Davis AM, Lineker SC, *et al.* Effectiveness of the primary therapist model for rheumatoid arthritis rehabilitation: a randomized controlled trial. *Arthritis Rheum* 2006;55:42-52.
- 86 Melikoglu MA, Karatay S, Senel K, *et al.* Association between dynamic exercise therapy and IGF-1 and IGFBP-3 concentrations in the patients with rheumatoid arthritis. *Rheumatol Int* 2006;26:309-13.
- 87 Hansen TM, Hansen G, Langgaard AM, *et al.* Longterm physical training in rheumatoid arthritis. A randomized trial with different training programs and blinded observers. *Scand J Rheumatol* 1993;22:107-12.
- 88 Nordström DC, Kontinen YT, Solovieva S, *et al.* In- and out-patient rehabilitation in rheumatoid arthritis. A controlled, open, longitudinal, cost-effectiveness study. *Scand J Rheumatol* 1996;25:200-6.
- 89 Minor MA, Hewett JE. Physical fitness and work capacity in women with rheumatoid arthritis. *Arthritis Care Res* 1995;8:146-54.
- 90 Noreau L, Martineau H, Roy L, *et al.* Effects of a modified dance-based exercise on cardiorespiratory fitness, psychological state and health status of persons with rheumatoid arthritis. *Am J Phys Med Rehabil* 1995;74:19-27.
- 91 Ekblom B, Lövgren O, Alderin M, *et al.* Effect of short-term physical training on patients with rheumatoid arthritis. a six-month follow-up study. *Scand J Rheumatol* 1975;4:87-91.
- 92 Nadareishvili Z, Michaud K, Hallenbeck JM, *et al.* Cardiovascular, rheumatologic, and pharmacologic predictors of stroke in patients with rheumatoid arthritis: a nested, case-control study. *Arthritis Rheum* 2008;59:1090-6.
- 93 Wolfe F, Michaud K. The risk of myocardial infarction and pharmacologic and nonpharmacologic myocardial infarction predictors in rheumatoid arthritis: a cohort and nested case-control analysis. *Arthritis Rheum* 2008;58:2612-21.
- 94 Stenström CH. Radiologically observed progression of joint destruction and its relationship with demographic factors, disease severity, and exercise frequency in patients with rheumatoid arthritis. *Phys Ther* 1994;74:32-9.
- 95 Lange E, Kucharski D, Svedlund S, *et al.* Effects of aerobic and resistance exercise in older adults with rheumatoid arthritis: a randomized controlled trial. *Arthritis Care Res* 2019;71:61-70.
- 96 Durcan L, Wilson F, Cunnane G. The effect of exercise on sleep and fatigue in rheumatoid arthritis: a randomized controlled study. *J Rheumatol* 2014;41:1966-73.
- 97 Breedland I, van Scheppingen C, Leijmsa M, *et al.* Effects of a group-based exercise and educational program on physical performance and disease self-management in rheumatoid arthritis: a randomized controlled study. *Phys Ther* 2011;91:879-93.
- 98 Hurkmans EJ, van den Berg MH, Runday KH, *et al.* Maintenance of physical activity after Internet-based physical activity interventions in patients with rheumatoid arthritis. *Rheumatology* 2010;49:167-72.
- 99 Flint-Wagner HG, Lisse J, Lohman TG, *et al.* Assessment of a sixteen-week training program on strength, pain, and function in rheumatoid arthritis patients. *J Clin Rheumatol* 2009;15:165-71.
- 100 Bultuis Y, Drossaers-Bakker KW, Taal E, *et al.* Arthritis patients show long-term benefits from 3 weeks intensive exercise training directly following hospital discharge. *Rheumatology* 2007;46:1712-7.
- 101 Neuberger GB, Aaronson LS, Gajewski B, *et al.* Predictors of exercise and effects of exercise on symptoms, function, aerobic fitness, and disease outcomes of rheumatoid arthritis. *Arthritis Rheum* 2007;57:943-52.
- 102 van den Berg MH, Runday HK, Peeters AJ, *et al.* Using internet technology to deliver a home-based physical activity intervention for patients with rheumatoid arthritis: a randomized controlled trial. *Arthritis Rheum* 2006;55:935-45.
- 103 Munneke M, de Jong Z, Zwiderman AH, *et al.* Effect of a high-intensity weight-bearing exercise program on radiologic damage progression of the large joints in subgroups of patients with rheumatoid arthritis. *Arthritis Rheum* 2005;53:410-7.
- 104 de Jong Z, Munneke M, Lems WF, *et al.* Slowing of bone loss in patients with rheumatoid arthritis by long-term high-intensity exercise: results of a randomized, controlled trial. *Arthritis Rheum* 2004;50:1066-76.
- 105 de Jong Z, Munneke M, Zwiderman AH, *et al.* Long term high intensity exercise and damage of small joints in rheumatoid arthritis. *Ann Rheum Dis* 2004;63:1399-405.
- 106 Häkkinen A, Sokka T, Hannonen P. A home-based two-year strength training period in early rheumatoid arthritis led to good long-term compliance: a five-year followup. *Arthritis Rheum* 2004;51:56-62.
- 107 Häkkinen A, Sokka T, Kautiainen H, *et al.* Sustained maintenance of exercise induced muscle strength gains and normal bone mineral density in patients with early rheumatoid arthritis: a 5 year follow up. *Ann Rheum Dis* 2004;63:910-6.
- 108 de Jong Z, Munneke M, Zwiderman AH, *et al.* Is a long-term high-intensity exercise program effective and safe in patients with rheumatoid arthritis? Results of a randomized controlled trial. *Arthritis Rheum* 2003;48:2415-24.
- 109 Westby MD, Wade JP, Rangno KK, *et al.* A randomized controlled trial to evaluate the effectiveness of an exercise program in women with rheumatoid arthritis taking low dose prednisone. *J Rheumatol* 2000;27:1674-80.
- 110 Häkkinen A, Sokka T, Kotaniemi A, *et al.* Dynamic strength training in patients with early rheumatoid arthritis increases muscle strength but not bone mineral density. *J Rheumatol* 1999;26:1257-63.
- 111 Lyngberg KK, Harreby M, Bentzen H, *et al.* Elderly rheumatoid arthritis patients on steroid treatment tolerate physical training without an increase in disease activity. *Arch Phys Med Rehabil* 1994;75:1189-95.
- 112 Ekdahl C, Andersson SI, Moritz U, *et al.* Dynamic versus static training in patients with rheumatoid arthritis. *Scand J Rheumatol* 1990;19:17-26.
- 113 Lyngberg K, Danneskiold-Samsøe B, Halskov O. The effect of physical training on patients with rheumatoid arthritis: changes in disease activity, muscle strength and aerobic capacity. A clinically controlled minimized cross-over study. *Clin Exp Rheumatol* 1988;6:253-60.
- 114 Nordemar R, Ekblom B, Zachrisson L, *et al.* Physical training in rheumatoid arthritis: a controlled long-term study. I. *Scand J Rheumatol* 1981;10:17-23.

- 115 Nordemar R. Physical training in rheumatoid arthritis: a controlled long-term study. II. Functional capacity and general attitudes. *Scand J Rheumatol* 1981;10:25–30.
- 116 Stavropoulos-Kalinoglou A, Metsios GS, Veldhuijzen van Zanten JJCS, et al. Individualised aerobic and resistance exercise training improves cardiorespiratory fitness and reduces cardiovascular risk in patients with rheumatoid arthritis. *Ann Rheum Dis* 2013;72:1819–25.
- 117 Löfgren M, Opava CH, Demmelmaier I, et al. Long-term, health-enhancing physical activity is associated with reduction of pain but not pain sensitivity or improved exercise-induced hypoalgesia in persons with rheumatoid arthritis. *Arthritis Res Ther* 2018;20:262.
- 118 Nordgren B, Fridén C, Demmelmaier I, et al. An outsourced health-enhancing physical activity programme for people with rheumatoid arthritis: exploration of adherence and response. *Rheumatology* 2015;54:1065–73.
- 119 Di Gioia L, Zincarelli C, Di Minno MND, et al. Effectiveness of a rehabilitative programme in improving fatigue and function in rheumatoid arthritis patients treated with biologics: a pilot study. *Clin Exp Rheumatol* 2013;31:285–8.
- 120 Strasser B, Leeb G, Strehlow C, et al. The effects of strength and endurance training in patients with rheumatoid arthritis. *Clin Rheumatol* 2011;30:623–32.
- 121 van der Giesen FJ, van Lankveld W, Hopman-Rock M, et al. Exploring the public health impact of an intensive exercise program for patients with rheumatoid arthritis: a dissemination and implementation study. *Arthritis Care Res* 2010;62:865–72.
- 122 de Jong Z, Munneke M, Kroon HM, et al. Long-term follow-up of a high-intensity exercise program in patients with rheumatoid arthritis. *Clin Rheumatol* 2009;28:663–71.
- 123 Neuberger GB, Press AN, Lindsley HB, et al. Effects of exercise on fatigue, aerobic fitness, and disease activity measures in persons with rheumatoid arthritis. *Res Nurs Health* 1997;20:195–204.
- 124 Al-Qubaeissy KY, Fatoye FA, Goodwin PC, et al. The effectiveness of hydrotherapy in the management of rheumatoid arthritis: a systematic review. *Musculoskeletal Care* 2013;11:3–18.
- 125 Siqueira US, Orsini Valente LG, de Mello MT, et al. Effectiveness of aquatic exercises in women with rheumatoid arthritis: a randomized, controlled, 16-Week Intervention-The HydRA trial. *Am J Phys Med Rehabil* 2017;96:167–75.
- 126 Eversden L, Maggs F, Nightingale P, et al. A pragmatic randomised controlled trial of hydrotherapy and land exercises on overall well being and quality of life in rheumatoid arthritis. *BMC Musculoskelet Disord* 2007;8:23.
- 127 Bilberg A, Ahlmén M, Mannerkorpi K. Moderately intensive exercise in a temperate pool for patients with rheumatoid arthritis: a randomized controlled study. *Rheumatology* 2005;44:502–8.
- 128 Lemmey AB, Marcora SM, Chester K, et al. Effects of high-intensity resistance training in patients with rheumatoid arthritis: a randomized controlled trial. *Arthritis Rheum* 2009;61:1726–34.
- 129 van den Ende CH, Breedveld FC, le Cessie S, et al. Effect of intensive exercise on patients with active rheumatoid arthritis: a randomised clinical trial. *Ann Rheum Dis* 2000;59:615–21.
- 130 van den Ende CH, Hazes JM, le Cessie S, et al. Comparison of high and low intensity training in well controlled rheumatoid arthritis. Results of a randomised clinical trial. *Ann Rheum Dis* 1996;55:798–805.
- 131 Lemmey AB, Williams SL, Marcora SM, et al. Are the benefits of a high-intensity progressive resistance training program sustained in rheumatoid arthritis patients? A 3-year followup study. *Arthritis Care Res* 2012;64:71–5.
- 132 Hammond A, Prior Y. The effectiveness of home hand exercise programmes in rheumatoid arthritis: a systematic review. *Br Med Bull* 2016;119:49–62.
- 133 Zernicke J, Kedor C, Müller A, et al. A prospective pilot study to evaluate an animated home-based physical exercise program as a treatment option for patients with rheumatoid arthritis. *BMC Musculoskelet Disord* 2016;17:351.
- 134 Seneca T, Hauge EM, Maribo T. Comparable effect of partly supervised and self-administered exercise programme in early rheumatoid arthritis—a randomised, controlled trial. *Dan Med J* 2015;62:A5127.
- 135 Hsieh L-F, Chen S-C, Chuang C-C, et al. Supervised aerobic exercise is more effective than home aerobic exercise in female Chinese patients with rheumatoid arthritis. *J Rehabil Med* 2009;41:332–7.
- 136 Stenström CH. Home exercise in rheumatoid arthritis functional class II: goal setting versus pain attention. *J Rheumatol* 1994;21:627–34.
- 137 Williams MA, Srikesavan C, Heine PJ, et al. Exercise for rheumatoid arthritis of the hand. *Cochrane Database Syst Rev* 2018;7:CD003832.
- 138 Baillet A, Vaillant M, Guinot M, et al. Efficacy of resistance exercises in rheumatoid arthritis: meta-analysis of randomized controlled trials. *Rheumatology* 2012;51:519–27.
- 139 Daien CI, Hua C, Combe B, et al. Non-pharmacological and pharmacological interventions in patients with early arthritis: a systematic literature review informing the 2016 update of EULAR recommendations for the management of early arthritis. *RMD Open* 2017;3:e000404.
- 140 Bergstra SA, Murgia A, Te Velde AF, et al. A systematic review into the effectiveness of hand exercise therapy in the treatment of rheumatoid arthritis. *Clin Rheumatol* 2014;33:1539–48.
- 141 Lo C-N, Xia G, Leung BP. The effect of nerve mobilization exercise in patients with rheumatoid arthritis: a pilot study. *Reumatismo* 2017;69:111–8.
- 142 Williamson E, McConkey C, Heine P, et al. Hand exercises for patients with rheumatoid arthritis: an extended follow-up of the SARAH randomised controlled trial. *BMJ Open* 2017;7:e013121.
- 143 Lourenzi FM, Jones A, Pereira DF, et al. Effectiveness of an overall progressive resistance strength program for improving the functional capacity of patients with rheumatoid arthritis: a randomized controlled trial. *Clin Rehabil* 2017;31:1482–91.
- 144 Lamb SE, Williamson EM, Heine PJ, et al. Exercises to improve function of the rheumatoid hand (SARAH): a randomised controlled trial. *Lancet* 2015;385:421–9.
- 145 Manning VL, Hurley MV, Scott DL, et al. Education, self-management, and upper extremity exercise training in people with rheumatoid arthritis: a randomized controlled trial. *Arthritis Care Res* 2014;66:217–27.
- 146 Dogu B, Sirzai H, Yilmaz F, et al. Effects of isotonic and isometric hand exercises on pain, hand functions, dexterity and quality of life in women with rheumatoid arthritis. *Rheumatol Int* 2013;33:2625–30.
- 147 Baillet A, Payraud E, Niderprim V-A, et al. A dynamic exercise programme to improve patients' disability in rheumatoid arthritis: a prospective randomized controlled trial. *Rheumatology* 2009;48:410–5.
- 148 Masiero S, Boniolo A, Wassermann L, et al. Effects of an educational-behavioral joint protection program on people with moderate to severe rheumatoid arthritis: a randomized controlled trial. *Clin Rheumatol* 2007;26:2043–50.
- 149 O'Brien AV, Jones P, Mullis R, et al. Conservative hand therapy treatments in rheumatoid arthritis—a randomized controlled trial. *Rheumatology* 2006;45:577–83.
- 150 Buljina AI, Taljanovic MS, Avdic DM, et al. Physical and exercise therapy for treatment of the rheumatoid hand. *Arthritis Rheum* 2001;45:392–7.
- 151 Scholten C, Brodowicz T, Graninger W, et al. Persistent functional and social benefit 5 years after a multidisciplinary arthritis training program. *Arch Phys Med Rehabil* 1999;80:1282–7.
- 152 Boström C, Harms-Ringdahl K, Karreskog H, et al. Effects of static and dynamic shoulder rotator exercises in women with rheumatoid arthritis: a randomised comparison of impairment, disability, handicap, and health. *Scand J Rheumatol* 1998;27:281–90.
- 153 Komatireddy GR, Leitch RW, Cella K, et al. Efficacy of low load resistive muscle training in patients with rheumatoid arthritis functional class II and III. *J Rheumatol* 1997;24:1531–9.
- 154 Hoenig H, Groff G, Pratt K, et al. A randomized controlled trial of home exercise on the rheumatoid hand. *J Rheumatol* 1993;20:785–9.
- 155 Dellhag B, Wollersjö I, Bjelle A. Effect of active hand exercise and wax bath treatment in rheumatoid arthritis patients. *Arthritis Care Res* 1992;5:87–92.
- 156 Marcora SM, Lemmey AB, Maddison PJ. Can progressive resistance training reverse cachexia in patients with rheumatoid arthritis? Results of a pilot study. *J Rheumatol* 2005;32:1031–9.
- 157 Göksel Karatepe A, Günaydin R, Türkmen G, et al. Effects of home-based exercise program on the functional status and the quality of life in patients with rheumatoid arthritis: 1-year follow-up study. *Rheumatol Int* 2011;31:171–6.
- 158 Han A, Robinson V, Judd M, et al. Tai chi for treating rheumatoid arthritis. *Cochrane Database Syst Rev* 2004;3:CD004849.
- 159 Wang C. Tai Chi improves pain and functional status in adults with rheumatoid arthritis: results of a pilot single-blinded randomized controlled trial. *Med Sport Sci* 2008;52:218–29.
- 160 Shin J-H, Lee Y, Kim SG, et al. The beneficial effects of Tai Chi exercise on endothelial function and arterial stiffness in elderly women with rheumatoid arthritis. *Arthritis Res Ther* 2015;17:380.

- 161 Lee H-Y, Hale CA, Hemingway B, *et al.* Tai Chi exercise and auricular acupressure for people with rheumatoid arthritis: an evaluation study. *J Clin Nurs* 2012;21:2812–22.
- 162 Uhlig T, Fongen C, Steen E, *et al.* Exploring Tai Chi in rheumatoid arthritis: a quantitative and qualitative study. *BMC Musculoskelet Disord* 2010;11:43.
- 163 Ward L, Stebbings S, Athens J, *et al.* Yoga for the management of pain and sleep in rheumatoid arthritis: a pilot randomized controlled trial. *Musculoskeletal Care* 2018;16:39–47.
- 164 Evans S, Moieni M, Lung K, *et al.* Impact of iyengar yoga on quality of life in young women with rheumatoid arthritis. *Clin J Pain* 2013;29:988–97.
- 165 Singh VK, Bhandari RB, Rana BB. Effect of yogic package on rheumatoid arthritis. *Indian J Physiol Pharmacol* 2011;55:329–35.
- 166 Badsha H, Chhabra V, Leibman C, *et al.* The benefits of yoga for rheumatoid arthritis: results of a preliminary, structured 8-week program. *Rheumatol Int* 2009;29:1417–21.
- 167 Bosch PR, Traustadóttir T, Howard P, *et al.* Functional and physiological effects of yoga in women with rheumatoid arthritis: a pilot study. *Altern Ther Health Med* 2009;15:24–31.
- 168 O'Dwyer T, Durcan L, Wilson F. Exercise and physical activity in systemic lupus erythematosus: a systematic review with meta-analyses. *Semin Arthritis Rheum* 2017;47:204–15.
- 169 Wu M-L, Yu K-H, Tsai J-C. The effectiveness of exercise in adults with systemic lupus erythematosus: a systematic review and meta-analysis to guide evidence-based practice. *Worldviews Evid Based Nurs* 2017;14:306–15.
- 170 Andrades C, Fuego C, Manrique-Arija S, *et al.* Management of cardiovascular risk in systemic lupus erythematosus: a systematic review. *Lupus* 2017;26:1407–19.
- 171 del Pino-Sedeño T, Trujillo-Martín MM, Ruiz-Irastorza G, *et al.* Effectiveness of nonpharmacologic interventions for decreasing fatigue in adults with systemic lupus erythematosus: a systematic review. *Arthritis Care Res* 2016;68:141–8.
- 172 Yuen HK, Cunningham MA. Optimal management of fatigue in patients with systemic lupus erythematosus: a systematic review. *Ther Clin Risk Manag* 2014;10:775–86.
- 173 Abrahão MI, Gomiero AB, Peccin MS, *et al.* Cardiovascular training vs. resistance training for improving quality of life and physical function in patients with systemic lupus erythematosus: a randomized controlled trial. *Scand J Rheumatol* 2016;45:197–201.
- 174 Bostrom C, Elfving B, Dupré B, *et al.* Effects of a one-year physical activity programme for women with systemic lupus erythematosus - a randomized controlled study. *Lupus* 2016;25:602–16.
- 175 Tench CM, McCarthy J, McCurdie I, *et al.* Fatigue in systemic lupus erythematosus: a randomized controlled trial of exercise. *Rheumatology* 2003;42:1050–4.
- 176 Robb-Nicholson LC, Daltroy L, Eaton H, *et al.* Effects of aerobic conditioning in lupus fatigue: a pilot study. *Br J Rheumatol* 1989;28:500–5.
- 177 Soriano-Maldonado A, Morillas-de-Laguno P, Sabio JM, *et al.* Effects of 12-week aerobic exercise on arterial stiffness, inflammation, and cardiorespiratory fitness in women with systemic lupus erythematosus: Non-Randomized controlled trial. *J Clin Med* 2018;7. doi:10.3390/jcm7120477. [Epub ahead of print: 24 11 2018].
- 178 dos Reis-Neto ET, da Silva AE, Monteiro CMdeC, *et al.* Supervised physical exercise improves endothelial function in patients with systemic lupus erythematosus. *Rheumatology* 2013;52:2187–95.
- 179 Carvalho MRPde, Sato EI, Tebexreni AS, *et al.* Effects of supervised cardiovascular training program on exercise tolerance, aerobic capacity, and quality of life in patients with systemic lupus erythematosus. *Arthritis Rheum* 2005;53:838–44.
- 180 Bogdanovic G, Stojanovich L, Djokovic A, *et al.* Physical activity program is helpful for improving quality of life in patients with systemic lupus erythematosus. *Tohoku J Exp Med* 2015;237:193–9.
- 181 Ramsey-Goldman R, Schilling EM, Dunlop D, *et al.* A pilot study on the effects of exercise in patients with systemic lupus erythematosus. *Arthritis Care Res* 2000;13:262–9.
- 182 Miossi R, Benatti FB, Lúciade de Sá Pinto A, *et al.* Using exercise training to counterbalance chronotropic incompetence and delayed heart rate recovery in systemic lupus erythematosus: a randomized trial. *Arthritis Care Res* 2012;64:1159–66.
- 183 Timóteo RP, Silva AF, Micheli DC, *et al.* Increased flexibility, pain reduction and unaltered levels of IL-10 and CD11b + lymphocytes in patients with systemic lupus erythematosus were associated with kinesiotherapy. *Lupus* 2018;27:1159–68.
- 184 Regel A, Sepriano A, Baraliakos X, *et al.* Efficacy and safety of non-pharmacological and non-biological pharmacological treatment: a systematic literature review Informing the 2016 update of the ASAS/EULAR recommendations for the management of axial spondyloarthritis. *RMD Open* 2017;3:e000397.
- 185 O'Dwyer T, O'Shea F, Wilson F. Exercise therapy for spondyloarthritis: a systematic review. *Rheumatol Int* 2014;34:887–902.
- 186 Karahan AY, Tok F, Yildirim P, *et al.* The effectiveness of Exergames in patients with ankylosing spondylitis: a randomized controlled trial. *Adv Clin Exp Med* 2016;25:931–6.
- 187 Jennings F, Oliveira HA, de Souza MC, *et al.* Effects of aerobic training in patients with ankylosing spondylitis. *J Rheumatol* 2015;42:2347–53.
- 188 Niedermann K, Sidelnikov E, Muggli C, *et al.* Effect of cardiovascular training on fitness and perceived disease activity in people with ankylosing spondylitis. *Arthritis Care Res* 2013;65:1844–52.
- 189 Sweeney S, Taylor G, Calin A. The effect of a home based exercise intervention package on outcome in ankylosing spondylitis: a randomized controlled trial. *J Rheumatol* 2002;29:763–6.
- 190 Ajeganova S, Wörnert M, Hafström I. A four-week team-rehabilitation programme in a warm climate decreases disability and improves health and body function for up to one year: a prospective study in Swedish patients with inflammatory joint diseases. *J Rehabil Med* 2016;48:711–8.
- 191 Brophy S, Cooksey R, Davies H, *et al.* The effect of physical activity and motivation on function in ankylosing spondylitis: a cohort study. *Semin Arthritis Rheum* 2013;42:619–26.
- 192 Ward MM. Predictors of the progression of functional disability in patients with ankylosing spondylitis. *J Rheumatol* 2002;29:1420–5.
- 193 Uhrin Z, Kuzis S, Ward MM. Exercise and changes in health status in patients with ankylosing spondylitis. *Arch Intern Med* 2000;160:2969–75.
- 194 Pécourneau V, Degboé Y, Barnetche T, *et al.* Effectiveness of exercise programs in ankylosing spondylitis: a meta-analysis of randomized controlled trials. *Arch Phys Med Rehabil* 2018;99:383–9.
- 195 Chang W, Tsou Y, Lee C. Comparison between specific exercises and physical therapy for managing patients with ankylosing spondylitis: a meta-analysis of randomized controlled trials. *Int J Clin Experiment Med* 2016;9:17028–39.
- 196 Millner JR, Barron JS, Beinke KM, *et al.* Exercise for ankylosing spondylitis: an evidence-based consensus statement. *Semin Arthritis Rheum* 2016;45:411–27.
- 197 Liang H, Zhang H, Ji H, *et al.* Effects of home-based exercise intervention on health-related quality of life for patients with ankylosing spondylitis: a meta-analysis. *Clin Rheumatol* 2015;34:1737–44.
- 198 Liang H, Li W-R, Zhang H, *et al.* Concurrent intervention with exercises and stabilized tumor necrosis factor inhibitor therapy reduced the disease activity in patients with ankylosing spondylitis: a meta-analysis. *Medicine* 2015;94:e2254.
- 199 Martins NA, Furtado GE, Campos MJ, *et al.* Exercise and ankylosing spondylitis with New York modified criteria: a systematic review of controlled trials with meta-analysis. *Acta Reumatol Port* 2014;39:298–308.
- 200 Sharan D, Rajkumar JS. Physiotherapy for ankylosing spondylitis: systematic review and a proposed rehabilitation protocol. *Curr Rheumatol Rev* 2017;13:121–5.
- 201 Sveaas SH, Bilberg A, Berg IJ, *et al.* High intensity exercise for 3 months reduces disease activity in axial spondyloarthritis (axSpA): a multicentre randomised trial of 100 patients. *Br J Sports Med* 2020;54:292–7.
- 202 Sveaas SH, Berg IJ, Fongen C, *et al.* High-intensity cardiorespiratory and strength exercises reduced emotional distress and fatigue in patients with axial spondyloarthritis: a randomized controlled pilot study. *Scand J Rheumatol* 2018;47:117–21.
- 203 Aydin T, Taşpınar Özgür, Saryıldız MA, *et al.* Evaluation of the effectiveness of home based or hospital based calisthenic exercises in patients with ankylosing spondylitis. *J Back Musculoskelet Rehabil* 2016;29:723–30.
- 204 Roşu MO, Ţopa I, Chiriac R, *et al.* Effects of Pilates, McKenzie and Heckscher training on disease activity, spinal motility and pulmonary function in patients with ankylosing spondylitis: a randomized controlled trial. *Rheumatol Int* 2014;34:367–72.
- 205 Sveaas SH, Berg IJ, Provan SA, *et al.* Efficacy of high intensity exercise on disease activity and cardiovascular risk in active axial spondyloarthritis: a randomized controlled pilot study. *PLoS One* 2014;9:e108688.
- 206 Kjekten I, Bo I, Rønningen A, *et al.* A three-week multidisciplinary in-patient rehabilitation programme had positive long-term effects

- in patients with ankylosing spondylitis: randomized controlled trial. *J Rehabil Med* 2013;45:260–7.
- 207 Analay Y, Ozcan E, Karan A, *et al.* The effectiveness of intensive group exercise on patients with ankylosing spondylitis. *Clin Rehabil* 2003;17:631–6.
- 208 Hidding A, van der Linden S, Gielen X, *et al.* Continuation of group physical therapy is necessary in ankylosing spondylitis: results of a randomized controlled trial. *Arthritis Care Res* 1994;7:90–6.
- 209 Hidding A, van der Linden S, Boers M, *et al.* Is group physical therapy superior to individualized therapy in ankylosing spondylitis? A randomized controlled trial. *Arthritis Care Res* 1993;6:117–25.
- 210 Kraag G, Stokes B, Groh J, *et al.* The effects of comprehensive home physiotherapy and supervision on patients with ankylosing spondylitis—a randomized controlled trial. *J Rheumatol* 1990;17:228–33.
- 211 Levitova A, Hulejova H, Spiritovic M, *et al.* Clinical improvement and reduction in serum calprotectin levels after an intensive exercise programme for patients with ankylosing spondylitis and non-radiographic axial spondyloarthritis. *Arthritis Res Ther* 2016;18:275.
- 212 Aytekin E, Caglar NS, Ozgonenel L, *et al.* Home-based exercise therapy in patients with ankylosing spondylitis: effects on pain, mobility, disease activity, quality of life, and respiratory functions. *Clin Rheumatol* 2012;31:91–7.
- 213 Viitanen JV, Heikkilä S. Functional changes in patients with spondylarthropathy. A controlled trial of the effects of short-term rehabilitation and 3-year follow-up. *Rheumatol Int* 2001;20:211–4.
- 214 Lubrano E, D'Angelo S, Parsons WJ, *et al.* Effectiveness of rehabilitation in active ankylosing spondylitis assessed by the ASAS response criteria. *Rheumatology* 2007;46:1672–5.
- 215 Band DA, Jones SD, Kennedy LG, *et al.* Which patients with ankylosing spondylitis derive most benefit from an inpatient management program? *J Rheumatol* 1997;24:2381–4.
- 216 Viitanen JV, Lehtinen K, Suni J, *et al.* Fifteen months' follow-up of intensive inpatient physiotherapy and exercise in ankylosing spondylitis. *Clin Rheumatol* 1995;14:413–9.
- 217 Kraag G, Stokes B, Groh J, *et al.* The effects of comprehensive home physiotherapy and supervision on patients with ankylosing spondylitis—an 8-month follow-up. *J Rheumatol* 1994;21:261–3.
- 218 Viitanen JV, Suni J, Kautiainen H, *et al.* Effect of physiotherapy on spinal mobility in ankylosing spondylitis. *Scand J Rheumatol* 1992;21:38–41.
- 219 Escalas C, Dalichamp M, Dougados M, *et al.* Evaluation of physiotherapy in a prospective cohort of early axial spondyloarthritis. Data from the DESIR cohort. *Joint Bone Spine* 2016;83:185–90.
- 220 Zão A, Cantista P. The role of land and aquatic exercise in ankylosing spondylitis: a systematic review. *Rheumatol Int* 2017;37:1979–90.
- 221 Dundar U, Solak O, Toktas H, *et al.* Effect of aquatic exercise on ankylosing spondylitis: a randomized controlled trial. *Rheumatol Int* 2014;34:1505–11.
- 222 Karapolat H, Eyigor S, Zoghi M, *et al.* Are swimming or aerobic exercise better than conventional exercise in ankylosing spondylitis patients? A randomized controlled study. *Eur J Phys Rehabil Med* 2009;45:449–57.
- 223 Hsieh L-F, Chuang C-C, Tseng C-S, *et al.* Combined home exercise is more effective than range-of-motion home exercise in patients with ankylosing spondylitis: a randomized controlled trial. *Biomed Res Int* 2014;2014:398190.
- 224 Rodríguez-Lozano C, Juanola X, Cruz-Martínez J, *et al.* Outcome of an education and home-based exercise programme for patients with ankylosing spondylitis: a nationwide randomized study. *Clin Exp Rheumatol* 2013;31:739–48.
- 225 Lim H-J, Moon Y-I, Lee MS. Effects of home-based daily exercise therapy on joint mobility, daily activity, pain, and depression in patients with ankylosing spondylitis. *Rheumatol Int* 2005;25:225–9.
- 226 Yigit S, Sahin Z, Demir SE, *et al.* Home-based exercise therapy in ankylosing spondylitis: short-term prospective study in patients receiving tumor necrosis factor alpha inhibitors. *Rheumatol Int* 2013;33:71–7.
- 227 Durmus D, Alayli G, Cil E, *et al.* Effects of a home-based exercise program on quality of life, fatigue, and depression in patients with ankylosing spondylitis. *Rheumatol Int* 2009;29:673–7.
- 228 Durmuş D, Alaylı G, Uzun O, *et al.* Effects of two exercise interventions on pulmonary functions in the patients with ankylosing spondylitis. *Joint Bone Spine* 2009;76:150–5.
- 229 Karapolat H, Akkoc Y, Sari I, *et al.* Comparison of group-based exercise versus home-based exercise in patients with ankylosing spondylitis: effects on Bath ankylosing spondylitis indices, quality of life and depression. *Clin Rheumatol* 2008;27:695–700.
- 230 Souza MCde, Jennings F, Morimoto H, *et al.* Swiss ball exercises improve muscle strength and walking performance in ankylosing spondylitis: a randomized controlled trial. *Rev Bras Reumatol Engl Ed* 2017;57:45–55.
- 231 Kasapoglu Aksoy M, Birtane M, Taştekin N, *et al.* The effectiveness of structured group education on ankylosing spondylitis patients. *J Clin Rheumatol* 2017;23:138–43.
- 232 Rosu OM, Ancuta C. McKenzie training in patients with early stages of ankylosing spondylitis: results of a 24-week controlled study. *Eur J Phys Rehabil Med* 2015;51:261–8.
- 233 Masiero S, Poli P, Bonaldo L, *et al.* Supervised training and home-based rehabilitation in patients with stabilized ankylosing spondylitis on TNF inhibitor treatment: a controlled clinical trial with a 12-month follow-up. *Clin Rehabil* 2014;28:562–72.
- 234 Altan L, Korkmaz N, Dizdar M, *et al.* Effect of Pilates training on people with ankylosing spondylitis. *Rheumatol Int* 2012;32:2093–9.
- 235 Masiero S, Bonaldo L, Pigatto M, *et al.* Rehabilitation treatment in patients with ankylosing spondylitis stabilized with tumor necrosis factor inhibitor therapy: a randomized controlled trial. *J Rheumatol* 2011;38:1335–42.
- 236 Fernández-de-Las-Peñas C, Alonso-Blanco C, Alguacil-Diego IM, *et al.* One-year follow-up of two exercise interventions for the management of patients with ankylosing spondylitis: a randomized controlled trial. *Am J Phys Med Rehabil* 2006;85:559–67.
- 237 Fernández-de-Las-Peñas C, Alonso-Blanco C, Morales-Cabezas M, *et al.* Two exercise interventions for the management of patients with ankylosing spondylitis: a randomized controlled trial. *Am J Phys Med Rehabil* 2005;84:407–19.
- 238 Gyurcsik ZN, András A, Bodnár N, *et al.* Improvement in pain intensity, spine stiffness, and mobility during a controlled individualized physiotherapy program in ankylosing spondylitis. *Rheumatol Int* 2012;32:3931–6.
- 239 Hulejová H, Levitová A, Kuklová M, *et al.* No effect of physiotherapy on the serum levels of adipocytokines in patients with ankylosing spondylitis. *Clin Rheumatol* 2012;31:67–71.
- 240 Ortancil O, Sarikaya S, Sapmaz P, *et al.* The effect(s) of a six-week home-based exercise program on the respiratory muscle and functional status in ankylosing spondylitis. *J Clin Rheumatol* 2009;15:68–70.
- 241 Roger-Silva D, Natour J, Moreira E, *et al.* A resistance exercise program improves functional capacity of patients with psoriatic arthritis: a randomized controlled trial. *Clin Rheumatol* 2018;37:389–95.
- 242 Chimenti MS, Triggianese P, Conigliaro P, *et al.* Self-reported adherence to a home-based exercise program among patients affected by psoriatic arthritis with minimal disease activity. *Drug Dev Res* 2014;75(Suppl 1):S57–9.
- 243 Antonioli CM, Bua G, Frigè A, *et al.* An individualized rehabilitation program in patients with systemic sclerosis may improve quality of life and hand mobility. *Clin Rheumatol* 2009;28:159–65.
- 244 Moran ME. Scleroderma and evidence based non-pharmaceutical treatment modalities for digital ulcers: a systematic review. *J Wound Care* 2014;23:510–6.
- 245 Rannou F, Boutron I, Mouthon L, *et al.* Personalized physical therapy versus usual care for patients with systemic sclerosis: a randomized controlled trial. *Arthritis Care Res* 2017;69:1050–9.
- 246 Schouffoer AA, Ninaber MK, Beart-van de Voorde LJJ, *et al.* Randomized comparison of a multidisciplinary team care program with usual care in patients with systemic sclerosis. *Arthritis Care Res* 2011;63:909–17.
- 247 Pinto ALS, Oliveira NC, Gualano B, *et al.* Efficacy and safety of concurrent training in systemic sclerosis. *J Strength Cond Res* 2011;25:1423–8.
- 248 Maddali Bongli S, Del Rosso A, Galluccio F, *et al.* Efficacy of a tailored rehabilitation program for systemic sclerosis. *Clin Exp Rheumatol* 2009;27:44–50.
- 249 Stefanantoni K, Sciarra I, Iannace N, *et al.* Occupational therapy integrated with a self-administered stretching program on systemic sclerosis patients with hand involvement. *Clin Exp Rheumatol* 2016;34(Suppl 100):157–61.
- 250 Horváth J, Bálint Z, Szép E, *et al.* Efficacy of intensive hand physical therapy in patients with systemic sclerosis. *Clin Exp Rheumatol* 2017;35(Suppl 106):159–66.
- 251 Mugii N, Matsushita T, Oohata S, *et al.* Long-term follow-up of finger passive range of motion in Japanese systemic sclerosis patients treated with self-administered stretching. *Mod Rheumatol* 2019;29:484–90.
- 252 Landim SF, Bertolo MB, Marcato de Abreu MF, *et al.* The evaluation of a home-based program for hands in patients with systemic sclerosis. *J Hand Ther* 2019;32:313–21.

- 253 Mugii N, Hasegawa M, Matsushita T, *et al.* The efficacy of self-administered stretching for finger joint motion in Japanese patients with systemic sclerosis. *J Rheumatol* 2006;33:1586–92.
- 254 Ma L, Sun R, Jia Z, *et al.* Clinical characteristics associated with subcutaneous tophi formation in Chinese gout patients: a retrospective study. *Clin Rheumatol* 2018;37:1359–65.
- 255 Adithya Acharya K, Sharma A. Evaluation of the efficacy of siravyadha and guduchi siddha yoga basti in the management of vatarakta with special reference to gout. *Int J Res Ayurveda Pharm* 2019;4:402–9.
- 256 Sadeghi A, Rad ZA, Sajedi B, *et al.* Effect of weight losing on the clinical status improvement of patients with knee osteoarthritis. *Rheumatol Clin* 2019;15:73–6.
- 257 O'Brien KM, Wiggers J, Williams A, *et al.* Telephone-based weight loss support for patients with knee osteoarthritis: a pragmatic randomised controlled trial. *Osteoarthritis Cartilage* 2018;26:485–94.
- 258 Allen KD, Oddone EZ, Coffman CJ, *et al.* Patient, provider, and combined interventions for managing osteoarthritis in primary care: a cluster randomized trial. *Ann Intern Med* 2017;166:401–11.
- 259 Allen KD, Yancy WS, Bosworth HB, *et al.* A combined patient and provider intervention for management of osteoarthritis in veterans. *Ann Intern Med* 2016;164:73–83.
- 260 Christensen R, Henriksen M, Leeds AR, *et al.* Effect of weight maintenance on symptoms of knee osteoarthritis in obese patients: a twelve-month randomized controlled trial. *Arthritis Care Res* 2015;67:640–50.
- 261 Hunter DJ, Beavers DP, Eckstein F, *et al.* The intensive diet and exercise for arthritis (IDEA) trial: 18-month radiographic and MRI outcomes. *Osteoarthritis Cartilage* 2015;23:1090–8.
- 262 Saraboon Y, Aree-Ue S, Maruo SJ. The effect of multifactorial intervention programs on health behavior and symptom control among community-dwelling overweight older adults with knee osteoarthritis. *Orthop Nurs* 2015;34:296–308.
- 263 Beavers DP, Beavers KM, Loeser RF, *et al.* The independent and combined effects of intensive weight loss and exercise training on bone mineral density in overweight and obese older adults with osteoarthritis. *Osteoarthritis Cartilage* 2014;22:726–33.
- 264 Henriksen M, Christensen R, Hunter DJ, *et al.* Structural changes in the knee during weight loss maintenance after a significant weight loss in obese patients with osteoarthritis: a report of secondary outcome analyses from a randomized controlled trial. *Osteoarthritis Cartilage* 2014;22:639–46.
- 265 Messier SP, Mihalko SL, Legault C, *et al.* Effects of intensive diet and exercise on knee joint loads, inflammation, and clinical outcomes among overweight and obese adults with knee osteoarthritis: the IDEA randomized clinical trial. *JAMA* 2013;310:1263–73.
- 266 Somers TJ, Blumenthal JA, Guilak F, *et al.* Pain coping skills training and lifestyle behavioral weight management in patients with knee osteoarthritis: a randomized controlled study. *Pain* 2012;153:1199–209.
- 267 Bliddal H, Leeds AR, Stigsgaard L, *et al.* Weight loss as treatment for knee osteoarthritis symptoms in obese patients: 1-year results from a randomised controlled trial. *Ann Rheum Dis* 2011;70:1798–803.
- 268 Gudbergensen H, Boesen M, Christensen R, *et al.* Radiographs and low field MRI (0.2T) as predictors of efficacy in a weight loss trial in obese women with knee osteoarthritis. *BMC Musculoskelet Disord* 2011;12.
- 269 Riecke BF, Christensen R, Christensen P, *et al.* Comparing two low-energy diets for the treatment of knee osteoarthritis symptoms in obese patients: a pragmatic randomized clinical trial. *Osteoarthritis Cartilage* 2010;18:746–54.
- 270 Ravaud P, Flipo RM, Boutron I. ARTIST (osteoarthritis intervention standardized) study of standardised consultation versus usual care for patients with osteoarthritis of the knee in primary care in France: pragmatic randomised controlled trial. *BMJ* 2009;338:b421.
- 271 Miller GD, Nicklas BJ, Loeser RF. Inflammatory biomarkers and physical function in older, obese adults with knee pain and self-reported osteoarthritis after intensive weight-loss therapy. *J Am Geriatr Soc* 2008;56:644–51.
- 272 Miller GD, Nicklas BJ, Davis C, *et al.* Intensive weight loss program improves physical function in older obese adults with knee osteoarthritis. *Obesity* 2006;14:1219–30.
- 273 Christensen R, Astrup A, Bliddal H. Weight loss: the treatment of choice for knee osteoarthritis? A randomized trial. *Osteoarthritis Cartilage* 2005;13:20–7.
- 274 Messier SP, Loeser RF, Miller GD, *et al.* Exercise and dietary weight loss in overweight and obese older adults with knee osteoarthritis: the arthritis, diet, and activity promotion trial. *Arthritis Rheum* 2004;50:1501–10.
- 275 Rejeski WJ, Focht BC, Messier SP, *et al.* Obese, older adults with knee osteoarthritis: weight loss, exercise, and quality of life. *Health Psychol* 2002;21:419–26.
- 276 Messier SP, Loeser RF, Mitchell MN, *et al.* Exercise and weight loss in obese older adults with knee osteoarthritis: a preliminary study. *J Am Geriatr Soc* 2000;48:1062–72.
- 277 Toda Y. The effect of energy restriction, walking, and exercise on lower extremity lean body mass in obese women with osteoarthritis of the knee. *J Orthop Sci* 2001;6:148–54.
- 278 Huang MH, Chen CH, Chen TW, *et al.* The effects of weight reduction on the rehabilitation of patients with knee osteoarthritis and obesity. *Arthritis Care Res* 2000;13:398–405.
- 279 Bartholdy C, Christensen R, Kristensen LE, *et al.* Association between weight loss and spontaneous changes in physical inactivity in overweight/obese individuals with knee osteoarthritis: an 8-week prospective cohort study. *Arthritis Care Res* 2020;72:397–404.
- 280 Aree-Ue S, Saraboon Y, Belza B. Long-Term adherence and effectiveness of a multicomponent intervention for community-dwelling overweight Thai older adults with knee osteoarthritis: 1-year follow up. *J Gerontol Nurs* 2017;43:40–8.
- 281 Atukorala I, Makovey J, Lawler L, *et al.* Is there a dose-response relationship between weight loss and symptom improvement in persons with knee osteoarthritis? *Arthritis Care Res* 2016;68:1106–14.
- 282 Bartels EM, Christensen R, Christensen P, *et al.* Effect of a 16 weeks weight loss program on osteoarthritis biomarkers in obese patients with knee osteoarthritis: a prospective cohort study. *Osteoarthritis Cartilage* 2014;22:1817–25.
- 283 Paans N, van den Akker-Scheek I, Dilling RG, *et al.* Effect of exercise and weight loss in people who have hip osteoarthritis and are overweight or obese: a prospective cohort study. *Phys Ther* 2013;93:137–46.
- 284 Gudbergensen H, Boesen M, Lohmander LS, *et al.* Weight loss is effective for symptomatic relief in obese subjects with knee osteoarthritis independently of joint damage severity assessed by high-field MRI and radiography. *Osteoarthritis Cartilage* 2012;20:495–502.
- 285 Bihlet AR, Byrjalsen I, Bay-Jensen A-C, *et al.* Identification of pain categories associated with change in pain in patients receiving placebo: data from two phase 3 randomized clinical trials in symptomatic knee osteoarthritis. *BMC Musculoskelet Disord* 2018;19:17.
- 286 Han A, Gellhorn AC. Trajectories of quality of life and associated risk factors in patients with knee osteoarthritis: findings from the osteoarthritis initiative. *Am J Phys Med Rehabil* 2018;97:620–7.
- 287 Jacobs CA, Vranceanu A-M, Thompson KL, *et al.* Rapid progression of knee pain and osteoarthritis biomarkers greatest for patients with combined obesity and depression: data from the osteoarthritis initiative. *Cartilage* 2020;11:38–46.
- 288 Pelletier J-P, Raynauld J-P, Abram F, *et al.* Exploring determinants predicting response to intra-articular hyaluronic acid treatment in symptomatic knee osteoarthritis: 9-year follow-up data from the osteoarthritis initiative. *Arthritis Res Ther* 2018;20:40.
- 289 Eymard F, Chevalier X, Conrozier T. Obesity and radiological severity are associated with viscosupplementation failure in patients with knee osteoarthritis. *J Orthop Res* 2017;35:2269–74.
- 290 Moyer R, Wirth W, Eckstein F. Longitudinal changes in magnetic resonance imaging-based measures of femorotibial cartilage thickness as a function of alignment and obesity: data from the osteoarthritis initiative. *Arthritis Care Res* 2017;69:959–65.
- 291 Bastick AN, Verkleij SPJ, Damen J, *et al.* Defining hip pain trajectories in early symptomatic hip osteoarthritis--5 year results from a nationwide prospective cohort study (CHECK). *Osteoarthritis Cartilage* 2016;24:768–75.
- 292 de Rezende MU, Hissadomi MI, de Campos GC, *et al.* One-Year results of an educational program on osteoarthritis: a prospective randomized controlled trial in Brazil. *Geriatr Orthop Surg Rehabil* 2016;7:86–94.
- 293 Beavers KM, Beavers DP, Newman JJ, *et al.* Effects of total and regional fat loss on plasma CRP and IL-6 in overweight and obese, older adults with knee osteoarthritis. *Osteoarthritis Cartilage* 2015;23:249–56.
- 294 Chatterjee D, McGee A, Strauss E, *et al.* Subchondral calcium phosphate is ineffective for bone marrow edema lesions in adults with advanced osteoarthritis. *Clin Orthop Relat Res* 2015;473:2334–42.
- 295 Karsdal MA, Bihlet A, Byrjalsen I, *et al.* OA phenotypes, rather than disease stage, drive structural progression--identification of

- structural progressors from 2 phase III randomized clinical studies with symptomatic knee OA. *Osteoarthritis Cartilage* 2015;23:550–8.
- 296 Kobayashi N, Inaba Y, Yukizawa Y, *et al.* Use of 18F-fluoride positron emission tomography as a predictor of the hip osteoarthritis progression. *Mod Rheumatol* 2015;25:925–30.
- 297 Magnusson K, Slatkowsky-Christensen B, van der Heijde D, *et al.* Body mass index and progressive hand osteoarthritis: data from the Oslo hand osteoarthritis cohort. *Scand J Rheumatol* 2015;44:331–6.
- 298 Gudbergesen H, Boesen M, Christensen R, *et al.* Changes in bone marrow lesions in response to weight-loss in obese knee osteoarthritis patients: a prospective cohort study. *BMC Musculoskelet Disord* 2013;14:106.
- 299 Perrot S, Bertin P. "Feeling better" or "feeling well" in usual care of hip and knee osteoarthritis pain: determination of cutoff points for patient acceptable symptom state (PASS) and minimal clinically important improvement (MCII) at rest and on movement in a national multicenter cohort study of 2414 patients with painful osteoarthritis. *Pain* 2013;154:248–56.
- 300 Coffman CJ, Allen KD, Woolson RF. Mixed-effects regression modeling of real-time momentary pain assessments in osteoarthritis (OA) patients. *Health Serv Outcomes Res Methodol* 2012;12:200–18.
- 301 Miyazaki T, Uchida K, Sato M, *et al.* Knee laxity after staircase exercise predicts radiographic disease progression in medial compartment knee osteoarthritis. *Arthritis Rheum* 2012;64:3908–16.
- 302 Rabago D, Zgierska A, Fortney L, *et al.* Hypertonic dextrose injections (prolotherapy) for knee osteoarthritis: results of a single-arm uncontrolled study with 1-year follow-up. *J Altern Complement Med* 2012;18:408–14.
- 303 Sands GH, Brown PB, Essex MN. The Efficacy of Continuous Versus Intermittent Celecoxib Treatment in Osteoarthritis Patients with Body Mass Index ≥ 30 and < 30 kg/m². *Open Rheumatol J* 2013;7:32–7.
- 304 Bartlett SJ, Ling SM, Mayo NE, *et al.* Identifying common trajectories of joint space narrowing over two years in knee osteoarthritis. *Arthritis Care Res* 2011;63:1722–8.
- 305 Bingham CO, Smugar SS, Wang H, *et al.* Predictors of response to cyclo-oxygenase-2 inhibitors in osteoarthritis: pooled results from two identical trials comparing etoricoxib, celecoxib, and placebo. *Pain Med* 2011;12:352–61.
- 306 Nishimura A, Hasegawa M, Kato K, *et al.* Risk factors for the incidence and progression of radiographic osteoarthritis of the knee among Japanese. *Int Orthop* 2011;35:839–43.
- 307 Richette P, Poitou C, Garnero P, *et al.* Benefits of massive weight loss on symptoms, systemic inflammation and cartilage turnover in obese patients with knee osteoarthritis. *Ann Rheum Dis* 2011;70:139–44.
- 308 Woollard JD, Gil AB, Sparto P, *et al.* Change in knee cartilage volume in individuals completing a therapeutic exercise program for knee osteoarthritis. *J Orthop Sports Phys Ther* 2011;41:708–22.
- 309 Yusuf E, Bijsterbosch J, Slagboom PE, *et al.* Body mass index and alignment and their interaction as risk factors for progression of knees with radiographic signs of osteoarthritis. *Osteoarthritis Cartilage* 2011;19:1117–22.
- 310 Shea MK, Houston DK, Nicklas BJ, *et al.* The effect of randomization to weight loss on total mortality in older overweight and obese adults: the ADAPT study. *J Gerontol A Biol Sci Med Sci* 2010;65:519–25.
- 311 Eckstein F, Maschek S, Wirth W, *et al.* One year change of knee cartilage morphology in the first release of participants from the osteoarthritis initiative progression subcohort: association with sex, body mass index, symptoms and radiographic osteoarthritis status. *Ann Rheum Dis* 2009;68:674–9.
- 312 Le Graverand M-PH, Brandt K, Mazzuca SA, *et al.* Progressive increase in body mass index is not associated with a progressive increase in joint space narrowing in obese women with osteoarthritis of the knee. *Ann Rheum Dis* 2009;68:1734–8.
- 313 Botha-Scheepers S, Dougados M, Ravaud P, *et al.* Effect of medial tibial plateau alignment on serial radiographs on the capacity to predict progression of knee osteoarthritis. *Osteoarthritis Cartilage* 2008;16:272–6.
- 314 Davies-Tuck ML, Wluka AE, Wang Y, *et al.* The natural history of cartilage defects in people with knee osteoarthritis. *Osteoarthritis Cartilage* 2008;16:337–42.
- 315 Pelletier J-P, Raynaud J-P, Berthiaume M-J, *et al.* Risk factors associated with the loss of cartilage volume on weight-bearing areas in knee osteoarthritis patients assessed by quantitative magnetic resonance imaging: a longitudinal study. *Arthritis Res Ther* 2007;9:R74.
- 316 Reijman M, Pols HAP, Bergink AP, *et al.* Body mass index associated with onset and progression of osteoarthritis of the knee but not of the hip: the Rotterdam study. *Ann Rheum Dis* 2007;66:158–62.
- 317 Raynaud J-P, Martel-Pelletier J, Berthiaume M-J, *et al.* Long term evaluation of disease progression through the quantitative magnetic resonance imaging of symptomatic knee osteoarthritis patients: correlation with clinical symptoms and radiographic changes. *Arthritis Res Ther* 2006;8:R21.
- 318 Wluka AE, Forbes A, Wang Y, *et al.* Knee cartilage loss in symptomatic knee osteoarthritis over 4.5 years. *Arthritis Res Ther* 2006;8:R90.
- 319 Sharma L, Cahue S, Song J, *et al.* Physical functioning over three years in knee osteoarthritis: role of psychosocial, local mechanical, and neuromuscular factors. *Arthritis Rheum* 2003;48:3359–70.
- 320 Cicuttini F, Wluka A, Wang Y, *et al.* The determinants of change in patella cartilage volume in osteoarthritic knees. *J Rheumatol* 2002;29:2615–9.
- 321 Wolfe F, Lane NE. The longterm outcome of osteoarthritis: rates and predictors of joint space narrowing in symptomatic patients with knee osteoarthritis. *J Rheumatol* 2002;29:139–46.
- 322 Detora LM, Krupa D, Bolognese J, *et al.* Rofecoxib shows consistent efficacy in osteoarthritis clinical trials, regardless of specific patient demographic and disease factors. *J Rheumatol* 2001;28:2494–503.
- 323 Cooper C, Snow S, McAlindon TE, *et al.* Risk factors for the incidence and progression of radiographic knee osteoarthritis. *Arthritis Rheum* 2000;43:995.
- 324 Harris PA, Hart DJ, Dacre JE, *et al.* The progression of radiological hand osteoarthritis over ten years: a clinical follow-up study. *Osteoarthritis Cartilage* 1994;2:247–52.
- 325 Ledingham J, Dawson S, Preston B, *et al.* Radiographic progression of hospital referred osteoarthritis of the hip. *Ann Rheum Dis* 1993;52:263–7.
- 326 Schouten JS, van den Ouweland FA, Valkenburg HA. A 12 year follow up study in the general population on prognostic factors of cartilage loss in osteoarthritis of the knee. *Ann Rheum Dis* 1992;51:932–7.
- 327 Berkhout B, Macfarlane JD, Cats A. Symptomatic osteoarthrosis of the knee: a follow-up study. *Br J Rheumatol* 1985;24:40–5.
- 328 Ahn JH, Kang HW, Yang TY, *et al.* Risk factors for radiographic progression of osteoarthritis after meniscus allograft transplantation. *Arthroscopy* 2016;32:2539–46.
- 329 Liu Y, Hazlewood GS, Kaplan GG, *et al.* Impact of obesity on remission and disease activity in rheumatoid arthritis: a systematic review and meta-analysis. *Arthritis Care Res* 2017;69:157–65.
- 330 Lupoli R, Pizzicato P, Scalaria A, *et al.* Impact of body weight on the achievement of minimal disease activity in patients with rheumatic diseases: a systematic review and meta-analysis. *Arthritis Res Ther* 2016;18:297.
- 331 Baghdadi LR, Woodman RJ, Shanahan EM, *et al.* The impact of traditional cardiovascular risk factors on cardiovascular outcomes in patients with rheumatoid arthritis: a systematic review and meta-analysis. *PLoS One* 2015;10:e0117952.
- 332 Baker JF, Stokes A, Mikuls TR, *et al.* Current and early life weight and associations with mortality in rheumatoid arthritis. *Clin Exp Rheumatol* 2019;37:768–73.
- 333 Hirose W, Harigai M, Uchiyama T, *et al.* Low body mass index and lymphocytopenia associate with Mycobacterium avium complex pulmonary disease in patients with rheumatoid arthritis. *Mod Rheumatol* 2019;29:105–12.
- 334 Lechtenboehmer CA, Jaeger VK, Kyburz D, *et al.* Brief report: influence of disease activity in rheumatoid arthritis on radiographic progression of concomitant interphalangeal joint osteoarthritis. *Arthritis Rheumatol* 2019;71:43–9.
- 335 England BR, Baker JF, Sayles H, *et al.* Body mass index, weight loss, and cause-specific mortality in rheumatoid arthritis. *Arthritis Care Res* 2018;70:11–18.
- 336 Nikiphorou E, Norton S, Young A, *et al.* The association of obesity with disease activity, functional ability and quality of life in early rheumatoid arthritis: data from the early rheumatoid arthritis Study/Early rheumatoid arthritis network UK prospective cohorts. *Rheumatology* 2018;57:1194–202.
- 337 Rydell E, Forslind K, Nilsson Jan-Åke, *et al.* Smoking, body mass index, disease activity, and the risk of rapid radiographic progression in patients with early rheumatoid arthritis. *Arthritis Res Ther* 2018;20:82.
- 338 Schulman E, Bartlett SJ, Schieir O, *et al.* Overweight, obesity, and the likelihood of achieving sustained remission in early rheumatoid arthritis: results from a multicenter prospective cohort study. *Arthritis Care Res* 2018;70:1185–91.

- 339 Smolen JS, Szumski A, Koenig AS, *et al.* Predictors of remission with etanercept-methotrexate induction therapy and loss of remission with etanercept maintenance, reduction, or withdrawal in moderately active rheumatoid arthritis: results of the PRESERVE trial. *Arthritis Res Ther* 2018;20:8.
- 340 Sparks JA, Chang S-C, Nguyen U-S, *et al.* Weight change during the early rheumatoid arthritis period and risk of subsequent mortality in women with rheumatoid arthritis and matched comparators. *Arthritis Rheumatol* 2018;70:18–29.
- 341 van der Heijde D, Durez P, Schett G, *et al.* Structural damage progression in patients with early rheumatoid arthritis treated with methotrexate, baricitinib, or baricitinib plus methotrexate based on clinical response in the phase 3 RA-BEGIN study. *Clin Rheumatol* 2018;37:2381–90.
- 342 Bird P, Nicholls D, Barrett R, *et al.* Longitudinal study of clinical prognostic factors in patients with early rheumatoid arthritis: the PREDICT study. *Int J Rheum Dis* 2017;20:460–8.
- 343 D'Agostino M-A, Alten R, Mysler E, *et al.* Body mass index and clinical response to intravenous or subcutaneous abatacept in patients with rheumatoid arthritis. *Clin Rheumatol* 2017;36:2655–65.
- 344 George MD, Østergaard M, Conaghan PG, *et al.* Obesity and rates of clinical remission and low MRI inflammation in rheumatoid arthritis. *Ann Rheum Dis* 2017;76:1743–6.
- 345 Iannone F, Courvoisier DS, Gottenberg JE, *et al.* Body mass does not impact the clinical response to intravenous abatacept in patients with rheumatoid arthritis. Analysis from the "pan-European registry collaboration for abatacept (PANABA)". *Clin Rheumatol* 2017;36:773–9.
- 346 Joo YB, Bang S-Y, Ryu JA, *et al.* Predictors of severe radiographic progression in patients with early rheumatoid arthritis: a prospective observational cohort study. *Int J Rheum Dis* 2017;20:1437–46.
- 347 Levitsky A, Brismar K, Hafström I, *et al.* Obesity is a strong predictor of worse clinical outcomes and treatment responses in early rheumatoid arthritis: results from the SWEFOT trial. *RMD Open* 2017;3:e000458.
- 348 Mariette X, Alten R, Nüßlein HG, *et al.* The effect of body mass index on clinical response to abatacept as a first-line biologic for rheumatoid arthritis: 6-month results from the 2-year, observational, prospective ACTION study. *Joint Bone Spine* 2017;84:571–6.
- 349 Miwa Y, Saito M, Furuya H, *et al.* Clinical characteristics of rheumatoid arthritis patients achieving functional remission after six months of non-tumor necrosis factor biological disease-modifying antirheumatic drugs (DMARDs) treatment. *Intern Med* 2017;56:2271–5.
- 350 Ramírez J, Narváez JA, Ruiz-Esquide V, *et al.* Clinical and sonographic biomarkers of structural damage progression in RA patients in clinical remission: a prospective study with 12 months follow-up. *Semin Arthritis Rheum* 2017;47:303–9.
- 351 Feldthausen C, Grimby-Ekman A, Forsblad-d'Elia H, *et al.* Explanatory factors and predictors of fatigue in persons with rheumatoid arthritis: a longitudinal study. *J Rehabil Med* 2016;48:469–76.
- 352 Gardette A, Ottaviani S, Sellam J, *et al.* Body mass index and response to abatacept in rheumatoid arthritis. *Eur J Clin Invest* 2016;46:1048–52.
- 353 Gardette A, Ottaviani S, Sellam J, *et al.* Body mass index and response to tocilizumab in rheumatoid arthritis: a real life study. *Clin Rheumatol* 2016;35:857–61.
- 354 McWilliams DF, Walsh DA. Factors predicting pain and early discontinuation of tumour necrosis factor- α -inhibitors in people with rheumatoid arthritis: results from the British Society for rheumatology biologics register. *BMC Musculoskelet Disord* 2016;17:337.
- 355 Tantayakom P, Koolvisoot A, Arromdee E, *et al.* Metabolic syndrome is associated with disease activity in patients with rheumatoid arthritis. *Joint Bone Spine* 2016;83:563–7.
- 356 Baker JF, Billig E, Michaud K, *et al.* Weight loss, the obesity paradox, and the risk of death in rheumatoid arthritis. *Arthritis Rheumatol* 2015;67:1711–7.
- 357 Iannone F, Fanizzi R, Notarnicola A, *et al.* Obesity reduces the drug survival of second line biological drugs following a first TNF- α inhibitor in rheumatoid arthritis patients. *Joint Bone Spine* 2015;82:187–91.
- 358 Pers Y-M, Godfrin-Valnet M, Lambert J, *et al.* Response to tocilizumab in rheumatoid arthritis is not influenced by the body mass index of the patient. *J Rheumatol* 2015;42:580–4.
- 359 Kim HW, Park JK, Yang J-A, *et al.* Comparison of tuberculosis incidence in ankylosing spondylitis and rheumatoid arthritis during tumor necrosis factor inhibitor treatment in an intermediate burden area. *Clin Rheumatol* 2014;33:1307–12.
- 360 Ochi K, Go Y, Furuya T, *et al.* Risk factors associated with the occurrence of distal radius fractures in Japanese patients with rheumatoid arthritis: a prospective observational cohort study. *Clin Rheumatol* 2014;33:477–83.
- 361 Sandberg MEC, Bengtsson C, Källberg H, *et al.* Overweight decreases the chance of achieving good response and low disease activity in early rheumatoid arthritis. *Ann Rheum Dis* 2014;73:2029–33.
- 362 Ajeganova S, Andersson ML, Hafström I, *et al.* Association of obesity with worse disease severity in rheumatoid arthritis as well as with comorbidities: a long-term followup from disease onset. *Arthritis Care Res* 2013;65:78–87.
- 363 Gremese E, Carletto A, Padovan M, *et al.* Obesity and reduction of the response rate to anti-tumor necrosis factor α in rheumatoid arthritis: an approach to a personalized medicine. *Arthritis Care Res* 2013;65:94–100.
- 364 Kanecki K, Tyszko P, Wisłowska M, *et al.* Preliminary report on a study of health-related quality of life in patients with rheumatoid arthritis. *Rheumatol Int* 2013;33:429–34.
- 365 Dirven L, Huizinga TWJ, Allaart CF. Risk factors for reported influenza and influenza-like symptoms in patients with rheumatoid arthritis. *Scand J Rheumatol* 2012;41:359–65.
- 366 Wevers-de Boer K, Visser K, Heimans L, *et al.* Remission induction therapy with methotrexate and prednisone in patients with early rheumatoid and undifferentiated arthritis (the IMPROVED study). *Ann Rheum Dis* 2012;71:1472–7.
- 367 Wolfe F, Michaud K. Effect of body mass index on mortality and clinical status in rheumatoid arthritis. *Arthritis Care Res* 2012;64:1471–9.
- 368 de Rooy DPC, van der Linden MPM, Knevel R, *et al.* Predicting arthritis outcomes--what can be learned from the Leiden Early Arthritis Clinic? *Rheumatology* 2011;50:93–100.
- 369 Klaasen R, Wijnbrandts CA, Gerlag DM, *et al.* Body mass index and clinical response to infliximab in rheumatoid arthritis. *Arthritis Rheum* 2011;63:359–64.
- 370 Liao KP, Weinblatt ME, Cui J, *et al.* Clinical predictors of erosion-free status in rheumatoid arthritis: a prospective cohort study. *Rheumatology* 2011;50:1473–9.
- 371 Tekaya R, Sahli H, Zribi S. [Obesity has a protective effect on radiographic joint damage in rheumatoid arthritis]. *Tunis Med* 2011;89.
- 372 Pye SR, Marshall T, Gaffney K, *et al.* Influence of arthritis and non-arthritis related factors on areal bone mineral density (BMDa) in women with longstanding inflammatory polyarthritis: a primary care based inception cohort. *BMC Musculoskelet Disord* 2010;11:106.
- 373 Verstappen SMM, Bakker MF, Heurkens AHM, *et al.* Adverse events and factors associated with toxicity in patients with early rheumatoid arthritis treated with methotrexate tight control therapy: the CAMERA study. *Ann Rheum Dis* 2010;69:1044–8.
- 374 Furuya T, Yamagiwa K, Ikai T, *et al.* Associated factors for falls and fear of falling in Japanese patients with rheumatoid arthritis. *Clin Rheumatol* 2009;28:1325–30.
- 375 Hashimoto J, Garnero P, van der Heijde D, *et al.* A combination of biochemical markers of cartilage and bone turnover, radiographic damage and body mass index to predict the progression of joint destruction in patients with rheumatoid arthritis treated with disease-modifying anti-rheumatic drugs. *Mod Rheumatol* 2009;19:273–82.
- 376 van der Helm-van Mil AHM, van der Kooij SM, Allaart CF, *et al.* A high body mass index has a protective effect on the amount of joint destruction in small joints in early rheumatoid arthritis. *Ann Rheum Dis* 2008;67:769–74.
- 377 Cohen J-D, Dougados M, Goupille P, *et al.* Health assessment questionnaire score is the best predictor of 5-year quality of life in early rheumatoid arthritis. *J Rheumatol* 2006;33:1936–41.
- 378 Escalante A, Haas RW, del Rincón I. Paradoxical effect of body mass index on survival in rheumatoid arthritis: role of comorbidity and systemic inflammation. *Arch Intern Med* 2005;165:1624–9.
- 379 Maradit-Kremers H, Nicola PJ, Crowson CS, *et al.* Cardiovascular death in rheumatoid arthritis: a population-based study. *Arthritis Rheum* 2005;52:722–32.
- 380 Sköldstam L, Brudin L, Hagfors L, *et al.* Weight reduction is not a major reason for improvement in rheumatoid arthritis from lacto-vegetarian, vegan or Mediterranean diets. *Nutr J* 2005;4:15.
- 381 Kremers HM, Nicola PJ, Crowson CS, *et al.* Prognostic importance of low body mass index in relation to cardiovascular mortality in rheumatoid arthritis. *Arthritis Rheum* 2004;50:3450–7.

- 382 Hoekstra M, van Ede AE, Haagsma CJ, *et al.* Factors associated with toxicity, final dose, and efficacy of methotrexate in patients with rheumatoid arthritis. *Ann Rheum Dis* 2003;62:423–6.
- 383 Krishnan E, Lingala B, Bruce B, *et al.* Disability in rheumatoid arthritis in the era of biological treatments. *Ann Rheum Dis* 2012;71:213–8.
- 384 Kreps DJ, Halperin F, Desai SP, *et al.* Association of weight loss with improved disease activity in patients with rheumatoid arthritis: a retrospective analysis using electronic medical record data. *Int J Clin Rheumatol* 2018;13:1–10.
- 385 Mori S, Yoshitama T, Hidaka T, *et al.* Comparative risk of hospitalized infection between biological agents in rheumatoid arthritis patients: a multicenter retrospective cohort study in Japan. *PLoS One* 2017;12:e0179179.
- 386 Rashid N, Lin AT, Aranda G, *et al.* Rates, factors, reasons, and economic impact associated with switching in rheumatoid arthritis patients newly initiated on biologic disease modifying anti-rheumatic drugs in an integrated healthcare system. *J Med Econ* 2016;19:568–75.
- 387 Ottaviani S, Gardette A, Roy C, *et al.* Body mass index and response to rituximab in rheumatoid arthritis. *Joint Bone Spine* 2015;82:432–6.
- 388 Ottaviani S, Gardette A, Tubach F, *et al.* Body mass index and response to infliximab in rheumatoid arthritis. *Clin Exp Rheumatol* 2015;33:478–83.
- 389 Sparks JA, Halperin F, Karlson JC, *et al.* Impact of bariatric surgery on patients with rheumatoid arthritis. *Arthritis Care Res* 2015;67:1619–26.
- 390 Gonzalez A, Maradit Kremers H, Crowson CS, *et al.* Do cardiovascular risk factors confer the same risk for cardiovascular outcomes in rheumatoid arthritis patients as in non-rheumatoid arthritis patients? *Ann Rheum Dis* 2008;67:64–9.
- 391 Kent PD, Luthra HS, Michet C. Risk factors for methotrexate-induced abnormal laboratory monitoring results in patients with rheumatoid arthritis. *J Rheumatol* 2004;31:1727–31.
- 392 Figueiredo-Braga M, Cornaby C, Bernardes M, *et al.* Correlation between physical markers and psychiatric health in a Portuguese systemic lupus erythematosus cohort: the role of suffering in chronic autoimmune disease. *PLoS One* 2018;13:e0195579.
- 393 Jacobs J, Korswagen L-A, Schilder AM, *et al.* Six-year follow-up study of bone mineral density in patients with systemic lupus erythematosus. *Osteoporos Int* 2013;24:1827–33.
- 394 Katz P, Yazdany J, Julian L, *et al.* Impact of obesity on functioning among women with systemic lupus erythematosus. *Arthritis Care Res* 2011;63:1357–64.
- 395 Chaiamnuy S, Bertoli AM, Fernández M, *et al.* The impact of increased body mass index on systemic lupus erythematosus: data from LUMINA, a multiethnic cohort (LUMINA XLVI) [corrected]. *J Clin Rheumatol* 2007;13:128–33.
- 396 Chaiamnuy S, Bertoli AM, Roseman JM, *et al.* African-American and Hispanic ethnicities, renal involvement and obesity predispose to hypertension in systemic lupus erythematosus: results from LUMINA, a multiethnic cohort (LUMINAXLV). *Ann Rheum Dis* 2007;66:618–22.
- 397 Uaratanawong S, Deesomchok U, Hirasuttikul N, *et al.* Four years follow-up of bone mineral density change in premenopausal women with systemic lupus erythematosus. *J Med Assoc Thai* 2004;87:1374–9.
- 398 Bruce IN, Gladman DD, Urowitz MB. Detection and modification of risk factors for coronary artery disease in patients with systemic lupus erythematosus: a quality improvement study. *Clin Exp Rheumatol* 1998;16:435–40.
- 399 Petri M, Perez-Gutthann S, Spence D, *et al.* Risk factors for coronary artery disease in patients with systemic lupus erythematosus. *Am J Med* 1992;93:513–9.
- 400 Hernández-Breijo B, Plasencia-Rodríguez C, Navarro-Compán V, *et al.* Association between concomitant csDMARDs and clinical response to TNF inhibitors in overweight patients with axial spondyloarthritis. *Arthritis Res Ther* 2019;21:66.
- 401 Jeong H, Eun YH, Kim IY, *et al.* Effect of tumor necrosis factor α inhibitors on spinal radiographic progression in patients with ankylosing spondylitis. *Int J Rheum Dis* 2018;21:1098–105.
- 402 Pedersen SJ, Weber U, Said-Nahal R. Structural progression rate decreases over time on serial radiography and magnetic resonance imaging of sacroiliac joints and spine in a five-year follow-up study of patients with ankylosing spondylitis treated with tumour necrosis factor inhibitor. *Scand J Rheumatol* 2018;1–13.
- 403 Maas F, Arends S, Wink FR, *et al.* Ankylosing spondylitis patients at risk of poor radiographic outcome show diminishing spinal radiographic progression during long-term treatment with TNF- α inhibitors. *PLoS One* 2017;12:e0177231.
- 404 Maas F, Spoorenberg A, van der Slik BPG, *et al.* Clinical risk factors for the presence and development of vertebral fractures in patients with ankylosing spondylitis. *Arthritis Care Res* 2017;69:694–702.
- 405 Micheroli R, Hebeisen M, Wildi LM, *et al.* Impact of obesity on the response to tumor necrosis factor inhibitors in axial spondyloarthritis. *Arthritis Res Ther* 2017;19:164.
- 406 Hwang J, Kim H-M, Jeong H, *et al.* Higher body mass index and anti-drug antibodies predict the discontinuation of anti-TNF agents in Korean patients with axial spondyloarthritis. *Rev Bras Reumatol Engl Ed* 2017;57:311–9.
- 407 van Weely SFE, Kneepkens EL, Nurmohamed MT, *et al.* Continuous improvement of physical functioning in ankylosing spondylitis patients by tumor necrosis factor inhibitors: three-year followup and predictors. *Arthritis Care Res* 2016;68:1522–9.
- 408 Maas F, Spoorenberg A, Brouwer E, *et al.* Spinal radiographic progression in patients with ankylosing spondylitis treated with TNF- α blocking therapy: a prospective longitudinal observational cohort study. *PLoS One* 2015;10:e0122693.
- 409 Gremese E, Bernardi S, Bonazza S, *et al.* Body weight, gender and response to TNF- α blockers in axial spondyloarthritis. *Rheumatology* 2014;53:875–81.
- 410 Ottaviani S, Allanore Y, Tubach F, *et al.* Body mass index influences the response to infliximab in ankylosing spondylitis. *Arthritis Res Ther* 2012;14:R115.
- 411 Di Minno MND, Peluso R, Iervolino S, *et al.* Weight loss and achievement of minimal disease activity in patients with psoriatic arthritis starting treatment with tumour necrosis factor α blockers. *Ann Rheum Dis* 2014;73:1157–62.
- 412 Klingberg E, Bilberg A, Björkman S, *et al.* Weight loss improves disease activity in patients with psoriatic arthritis and obesity: an interventional study. *Arthritis Res Ther* 2019;21.
- 413 Polachek A, Li S, Chandran V, *et al.* Clinical Enthesitis in a prospective longitudinal psoriatic arthritis cohort: incidence, prevalence, characteristics, and outcome. *Arthritis Care Res* 2017;69:1685–91.
- 414 Højgaard P, Glinthorg B, Kristensen LE, *et al.* The influence of obesity on response to tumour necrosis factor- α inhibitors in psoriatic arthritis: results from the DANBIO and ICEBIO registries. *Rheumatology* 2016;55:2191–9.
- 415 Eder L, Thavaneswaran A, Chandran V, *et al.* Obesity is associated with a lower probability of achieving sustained minimal disease activity state among patients with psoriatic arthritis. *Ann Rheum Dis* 2015;74:813–7.
- 416 Mease PJ, Collier DH, Saunders KC, *et al.* Comparative effectiveness of biologic monotherapy versus combination therapy for patients with psoriatic arthritis: results from the Corrona registry. *RMD Open* 2015;1:e000181.
- 417 di Minno MND, Peluso R, Iervolino S, *et al.* Obesity and the prediction of minimal disease activity: a prospective study in psoriatic arthritis. *Arthritis Care Res* 2013;65:141–7.
- 418 Iannone F, Fanizzi R, Scioscia C, *et al.* Body mass does not affect the remission of psoriatic arthritis patients on anti-TNF- α therapy. *Scand J Rheumatol* 2013;42:41–4.
- 419 Haddad A, Thavaneswaran A, Toloza S, *et al.* Diffuse idiopathic skeletal hyperostosis in psoriatic arthritis. *J Rheumatol* 2013;40:1367–73.
- 420 Marini C, Formichi B, Bauleo C, *et al.* Survival protection by bodyweight in isolated scleroderma-related pulmonary artery hypertension. *Intern Emerg Med* 2016;11:941–52.
- 421 Assasi S, Del Junco D, Sutter K, *et al.* Clinical and genetic factors predictive of mortality in early systemic sclerosis. *Arthritis Rheum* 2009;61:1403–11.
- 422 Nielsen SM, Bartels EM, Henriksen M, *et al.* Weight loss for overweight and obese individuals with gout: a systematic review of longitudinal studies. *Ann Rheum Dis* 2017;76:1870–82.
- 423 Dessein PH, Shipton EA, Stanwix AE, *et al.* Beneficial effects of weight loss associated with moderate calorie/carbohydrate restriction, and increased proportional intake of protein and unsaturated fat on serum urate and lipoprotein levels in gout: a pilot study. *Ann Rheum Dis* 2000;59:539–43.
- 424 Nguyen U-SDT, Zhang Y, Louie-Gao Q, *et al.* Obesity paradox in recurrent attacks of gout in observational studies: clarification and remedy. *Arthritis Care Res* 2017;69:561–6.
- 425 Romero-Talamás H, Daigle CR, Aminian A, *et al.* The effect of bariatric surgery on gout: a comparative study. *Surg Obes Relat Dis* 2014;10:1161–5.
- 426 Su BY-J, Lai H-M, Chen C-J, *et al.* Ischemia heart disease and greater waist circumference are risk factors of renal function deterioration in male gout patients. *Clin Rheumatol* 2008;27:581–6.

- 427 Abhishek A, Valdes AM, Zhang W, *et al.* Association of serum uric acid and disease duration with frequent gout attacks: a case-control study. *Arthritis Care Res* 2016;68:1573–7.
- 428 Alvarez-Nemegyei J, Cen-Pisté JC, Medina-Escobedo M, *et al.* Factors associated with musculoskeletal disability and chronic renal failure in clinically diagnosed primary gout. *J Rheumatol* 2005;32:1923–7.
- 429 Gwinnutt JM, Verstappen SM, Humphreys JH. The impact of lifestyle behaviours, physical activity and smoking on morbidity and mortality in patients with rheumatoid arthritis. *Best Pract Res Clin Rheumatol* 2020;34:101562.
- 430 Veldhuijzen van Zanten JJCS, Rouse PC, Hale ED, *et al.* Perceived barriers, facilitators and benefits for regular physical activity and exercise in patients with rheumatoid arthritis: a review of the literature. *Sports Med* 2015;45:1401–12.
- 431 Gwinnutt JM, Alsafar H, Hyrich KL, *et al.* Do people with rheumatoid arthritis maintain their physical activity level at treatment onset over the first year of methotrexate therapy? *Rheumatology* 2021;60:4633–42.
- 432 Klein-Wieringa IR, van der Linden MPM, Knevel R, *et al.* Baseline serum adipokine levels predict radiographic progression in early rheumatoid arthritis. *Arthritis Rheum* 2011;63:2567–74.
- 433 Shin A, Shin S, Kim JH, *et al.* Association between socioeconomic status and comorbidities among patients with rheumatoid arthritis: results of a nationwide cross-sectional survey. *Rheumatology* 2019;58:1617–22.
- 434 Björk M, Dragioti E, Alexandersson H, *et al.* Inflammatory arthritis and the effect of physical activity on quality of life and self-reported function: a systematic review and meta-analysis. *Arthritis Care Res* 2022;74:31–43.
- 435 Ortolan A, Lorenzin M, Felicetti M, *et al.* Do obesity and overweight influence disease activity measures in axial spondyloarthritis? A systematic review and meta-analysis. *Arthritis Care Res* 2021;73:1815–25.