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Published in:
Musculoskeletal Science and Practice

DOI:
[10.1016/j.msksp.2023.102858](https://doi.org/10.1016/j.msksp.2023.102858)

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Recommended citation(APA):
Sattler, L., Kan, A., Hing, W., & Vertullo, C. (2023). The addition of structured lifestyle modifications to a traditional exercise program for the management of patients with knee osteoarthritis: A systematic review and meta-analysis of randomised trials. *Musculoskeletal Science and Practice*, 68, 1-18. Article 102858. Advance online publication. <https://doi.org/10.1016/j.msksp.2023.102858>

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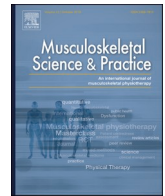
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Musculoskeletal Science and Practice

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Systematic review



The addition of structured lifestyle modifications to a traditional exercise program for the management of patients with knee osteoarthritis: A systematic review and meta-analysis of randomised trials

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ARTICLE INFO

Keywords:

Exercise
Rehabilitation
Physiotherapy
Physical therapy
Knee osteoarthritis
Lifestyle modifications

ABSTRACT

Background: Guidelines recommend exercise for the management of knee osteoarthritis (OA), however, recently it has been suggested that including additional lifestyle modifications with a traditional exercise program may elicit greater benefits than exercise alone.

Objectives: To investigate the influence of the addition of lifestyle modifications to a traditional exercise program, with respect to functional outcomes and quality of life among individuals with knee OA.

Design: Systematic review and meta-analysis.

Methods: Four databases were searched to identify randomised controlled trials comparing an exercise program, which included the addition of lifestyle modifications, to an exercise program alone in individuals with knee OA. Methodological quality of included studies was assessed via the PEDro scale. Results synthesis through meta-analysis using a random effects model was conducted to determine the pooled effect on eligible outcomes and a GRADE approach was utilised to rate the certainty of evidence.

Results: Meta-analysis of seven studies showed the inclusion of lifestyle modifications to an exercise program can further decrease pain intensity (SMD -0.68 [95% CI -1.26 to -0.10]), improve joint stiffness (MD -0.69 [95% CI -1.21, -0.17]) and increase physical function (MD -1.26 s ([95% CI -1.34, -1.17]) at six-months. Individual results showed improvements in quality of life with the addition of lifestyle modifications, however, this was not demonstrated through meta-analysis.

Conclusion: This systematic review supports the inclusion of additional lifestyle modifications to a traditional exercise program, for pain intensity, joint stiffness and physical function for individuals with knee OA.

Trial registration: PROSPERO registration number: CRD42021279594.

1. Background

Individuals with knee osteoarthritis (OA) often present with pain and disability, resulting in impaired function and leading to poorer quality of life (Bennell and Hinman, 2011; Hawker et al.; Vitaloni et al.). The subsequent decrease in physical activity may also contribute to muscle weakness and increase the risk of systemic disease development, resulting in further disability (Bennell and Hinman, 2011; Franssen et al., 2015; Stewart). Given the growing ageing population combined with rising obesity rates, an increase in knee OA prevalence has also been projected (Bennell and Hinman, 2011; Cross et al.; Woolf and Pfleger; Ackerman et al.), placing an ever-increasing financial burden on

healthcare systems (Cross et al.; Mahendira et al.; Chen et al., 1941). With no known cure for knee OA, current non-operative management focuses on relieving pain and reducing symptoms along with improving physical function and capacity (DeRogatis et al.; Smink et al.). Exercise is often a preferred conservative treatment amongst clinicians as it is non-invasive, easily accessible and has minimal adverse effect risk (Cross et al.). With the aim of increasing an individual's physical activity level and muscle strength, there is high-quality evidence to support that an exercise program can reduce pain and disability associated with knee OA (Bennell and Hinman, 2011; Franssen et al., 2015; Smink et al.; Bannuru et al., 2019). The subsequent improvement in quality of life, pain and function may also delay the need for surgical intervention

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Received 31 May 2023; Received in revised form 2 August 2023; Accepted 12 September 2023

Available online 29 September 2023

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(Husted et al.).

To date, most studies exploring the efficacy of traditional exercise in managing knee OA have focused primarily on elements of lower limb strength and conditioning (Bennell and Hinman, 2011; Juhl et al., 2014; Li et al., 2016; Roddy et al., 2005; Tanaka et al., 2013). This includes the comparison between open and closed kinetic chain, concentric and/or eccentric, weight-bearing versus non-weight-bearing and aerobic exercises. Additionally, balance and joint proprioception, in the form of neuromuscular training have also been investigated. Whilst evidence surrounding the efficacy of exercise for short-term benefits is well established, there is also growing support for including lifestyle modifications and mind-body exercises into traditional exercise programs to enhance long-term effects (Mihalko et al., 2019; Ye et al., 2014). In line with national medical association guidelines (Bannuru et al., 2019; Fernandes et al., 2013; Kolasinski et al., 2019; RACGP, 2018; Bruyère et al.), some of the recommendations for lifestyle modifications other than traditional exercise include disease education, self-care and pain coping strategies, dietary and weight loss programs, tai chi, yoga, and workshops targeting goal setting, motivation, and lifestyle advice (Bennell and Hinman, 2011; Kolasinski et al., 2019; Kuru Çolak et al.; Deepeshwar et al., 2018; Brierley et al., 2021). The subsequent changes to lifestyle habits and behaviours may increase overall physical activity levels and prevent the development, or progression, of comorbidities (Dunlop et al., 2011; Gay et al., 2016). This could improve long-term morbidity and mortality in populations who are more at risk of metabolic and cardiovascular disease (Dunlop et al., 2011; Gay et al., 2016). However, it should be noted that the provision of additional lifestyle modification interventions to a traditional exercise program will likely be associated with increased costs to the patient and health care provider and therefore the benefits of the inclusion of these should be examined (Mazzei et al., 2021).

Although past reviews have reported on the efficacy of land-based exercises for knee OA, there appears to be no systematic review examining the addition of other lifestyle modifications to exercise for the management of knee OA (Fransen et al., 2015; Anwer et al., 2001). Given the current recommendations for incorporating additional lifestyle modifications along with traditional exercise in conservative knee OA management, the purpose of this review is to explore the available research to determine if there is an evidence base for this. Therefore, this review aims to investigate the influence of the addition of lifestyle modifications to an exercise program, compared to a traditional exercise program in isolation, with respect to outcomes of pain, function, and quality of life for individuals with knee OA.

2. Methods

2.1. Data sources and search strategy

This study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis PRISMA statement (Page et al., 2021), and the study protocol was prospectively registered in PROSPERO (CRD42021279594).

A population, intervention, control, outcomes (PICO) framework was used to refine the clinical question and inform the search and eligibility criteria. A baseline search strategy was created for the PubMed database, and modified for CINAHL, SPORTDiscus, and PEDro databases using SR-Accelerator Polyglot software (Clark et al., a, b) (Appendix A). Key terms in the search strategy were as follows: exercise, rehabilitation, physiotherapy, physical therapy, and knee osteoarthritis. Databases were electronically searched from inception to September 11, 2022 to identify eligible studies.

2.2. Study eligibility

Studies meeting the PICO (population, intervention/exposure, comparison, and outcome) criteria were included in this review:

1. Population: Adults >18 years of age with clinically diagnosed unilateral or bilateral knee OA
2. Intervention: A management program including the addition of other lifestyle modifications to a traditional exercise program.
3. Comparison: Traditional exercise program alone.
4. Outcomes of interest: At least one of the following was required, pain intensity, quality of life, physical function, such as mobility and ability to perform functional tasks.

Exclusion criteria: (1) If the population of interest was that of a chronic cardiovascular, neurological, or metabolic disease condition in addition to diagnosed knee OA, post-surgical population, (2) the publication was not available in full text.

2.3. Selection and data collection process

After the removal of duplicates, two authors (AK, LS) independently carried out a title and abstract screen, followed by a full-text screen using SR-Accelerator Screenatron software (Clark et al., a, b) to identify studies that met the predefined eligibility criteria. Any disagreements on final study inclusion were resolved through consensus discussion with a third author (WH). Population characteristics, intervention protocol/time frame, eligibility criteria, outcome measures and results of individual studies were extracted independently by two authors (AK, LS) and recorded in a table adapted from the Cochrane Handbook for Systematic Reviews of Interventions (Table 1) (Cumpston et al.).

2.4. Assessment of methodological quality

Assessment of methodological quality within the selected studies was carried out independently by two authors (AK, LS) using the PEDro scale (Moseley et al., 2002). The PEDro scale is designed to assess the internal validity and risk of bias of a clinical trial (Moseley et al., 2002). Encompassing 11 yes or no check-point items, studies are scored out of 10 (item 1 is not included in the calculation). Studies with a score higher than 6 were considered to have a good methodological quality, whilst studies that receive a score of 4–6 points and 0–3 points were considered to have a fair, and poor methodological quality, respectively (Moseley et al., 2002). After the methodological quality of each study was scored independently, the Kappa coefficient of inter-rater reliability was calculated (IBM SPSS Statistics, Version 27.0. Armonk, NY: IBM Corp) to assess the agreement between the two reviewers (Landis et al.). Where there was disagreement on an individual item, a third author (WH) adjudicated to achieve consensus.

2.5. Synthesis methods

Individual study results were described through narrative and tabular synthesis. Meta-analysis statistical analyses were completed using Review Manager software (RevMan, Version 5.4; The Cochrane Collaboration, 2020), to report on the overall effectiveness of the intervention on outcomes from eligible studies. Studies were eligible for quantitative synthesis through meta-analysis if an outcome measure was present across two or more of the included studies, utilised similar time points for assessment, and reported the changes within-group mean differences (MD) and standard deviations (SD). If the SD was not provided, then it was determined from reported means and confidence intervals from the outcome results utilizing a RevMan calculator. As the effect of the intervention between studies was deemed to be variable concerning intervention dosage and type, a random-effects model was applied. The heterogeneity of study outcomes was determined via the I^2 index, I^2 values from 75 to 100% were seen as having considerable heterogeneity (Cochrane Handbook for Systematic Reviews of Interventions, Version 6.3, 2002). Values were considered statistically significant where $p < 0.05$. In cases where it was not possible to undertake meta-analysis such as in instances where only one study

Table 1
Study demographics.

Author, Year, Country Title	Control No of participants Sex (M/F) Mean age (years)	Experimental No of participants Sex (M/F) Mean age (years)			PEDRO Score (/10)
		Group 1	Group 2	Group 3	
Alfieri et al., 2020, Brazil	Efficacy of an exercise program combined with lifestyle education in patients with knee osteoarthritis 17 5/12 64.4	22 3/19 63.7			6
Bennell et al., 2016, Aus	Physical therapist-delivered pain coping skills training and exercise for knee osteoarthritis: randomised controlled trial 75 44/30 62.7	74 45/29 63	73 44/29 64.6		7
Bennell et al., 2017, Aus	Telephone coaching to enhance a home-based physical activity program for knee OA: A randomised clinical trial 84 27/57 63.4	84 35/49 61.1			8
Bennell et al., 2020, Aus	Behaviour changes text messages for home exercise adherence in knee osteoarthritis: Randomised Trial 54 15/39 62.9	56 21/35 61.7			9
Bokaeian et al., 2021, Iran	Effects of an exercise therapy targeting knee kinetics on pain, function, and gait kinetics in patients with knee OA: An RCT 18 4/14 56.7	22 6/16 54.9	19 4/15 57		7
Chen, 2019, China	Benefits of a transtheoretical model-based program on exercise adherence in older adults with knee OA: An RCT 72 4/68 68.71	89 8/81 67.09			6
Farr et al., 2010, USA	Progressive resistance training improves overall physical activity levels in patients with early OA of the knee: An RCT 57 16/41 55.8	52 14/38 55.5	62 13/49 54.2		5
Focht et al., 2014	Group-mediated physical activity promotion and mobility in sedentary patients with knee OA: results from the IMPACT-Pilot trial 40 9/31 63.6	40 4/36 63.4			6
Jenkinson et al., 2009	Effects of dietary intervention and quadriceps strengthening exercises on pain and function in overweight people with knee pain: RCT 76 3/73 61.5	122 43/79 61.7	82 26/56 61.1	109 36/73 61.1	7
Keefe et al., 2004, USA	Effects of spouse-assisted coping skills training and exercise training in patients with osteoarthritic knee pain: An RCT 18 7/11 57.56	18 9/9 60	16 10/6 60.25	20 7/13 60.20	3
Messier et al., 2004, USA	Exercise and dietary weight loss in overweight and obese older adults with knee OA 78 25/53 69	82 33/49 68	80 18/51 69	76 18/51 76	8
Mihalko, 2018, USA	Effects of intensive diet and exercise on self-efficacy in overweight and obese adults with knee OA: the IDEA RCT 150 42/108 65.5	152 44/ 108	152 43/ 109		6
Rejeski et al., 2002, USA	Obese, older adults with knee OA: weight loss, exercise, and quality of life 68 22/46 68.59	69 18/51 68.09	73 19/54 68.09	68 18/50 5.62	6
Veenhof et al., 2006, Netherlands	Effectiveness of Behavioural Graded Activity in Patients With Osteoarthritis of the Hip and/or Knee: A Randomized Clinical Trial 103 22/81 64.5	97 24/73 65.1			7
Wang et al., 2016, China	Comparative Effectiveness of Tai Chi Versus Physical Therapy for Knee Osteoarthritis: A Randomized Trial 98 30/68 60.1	106 31/75 60.3			7
Wang et al., 2020, China	The effect of transtheoretical model-lead intervention for knee osteoarthritis in older adults: a cluster randomized trial 86 10/93 68.81	103 4/82 67.38			7

M Male, F Female, RCT Randomised controlled trial.

reported on an outcome, data was extracted into tables and individual results were presented.

2.6. Certainty of evidence

To assess the certainty of the evidence for each meta-analysis result, the Grading of Recommendation Assessment, Development, and Evaluation (GRADE) approach was utilised (Schünemann et al., 2019; Guyatt et al., 2008). The ratings for the certainty of evidence were performed independently by two authors (AK, LS) and any disagreements were resolved through discussion with a third author (WH). The certainty of the evidence for each meta-analysis result was graded high (Fransen et al., 2015), medium (Vitaloni et al.), low (Hawker et al.) or very low certainty (Bennell and Hinman, 2011) (Schünemann et al., 2019; Guyatt et al., 2008). As the design for all included studies were randomized controlled trials each outcome began with a high-certainty

rating. Studies were then downgraded one place if there was (Bennell and Hinman, 2011) Risk of bias or limitations in the detailed design and implementation (PEDro 50%) (Hawker et al.), Unexplained heterogeneity or inconsistency of results ($I^2 = >50\%$) (Vitaloni et al.), Indirectness of evidence (Fransen et al., 2015) Imprecision of results (5% CI > 0.8 MD) or (Stewart) High probability of publication bias (Schünemann et al., 2019; Guyatt et al., 2008).

3. Results

3.1. Study selection

The initial search yielded 5879 studies, and after the removal of duplicates, 3845 remained. Following the title and abstract screen, 51 studies were further screened in full text, leaving a final 16 studies included in this review (Mihalko et al., 2019; Alfieri et al., 2020; Bennell

et al., 2016, 2017, 2020; Chen et al., 2020; Farr et al., 2010; Focht et al., 2014; Jenkinson et al., 2009; Keefe et al., 2004; Messier et al., 2004; Veenhof et al., 2006; Wang et al., 2016, 2020; Rejeski et al., 2002; Bokaeian et al., 2021). The complete study screening and selection process is shown in Fig. 1. Flow diagram of included studies.

3.2. Methodological quality appraisal

PEDro scores for the methodical quality of individual studies are reported in Table 1, with an average PEDro score of 7/10 across all studies (mean = 6.56, SD = 1.32), indicating overall good methodological quality. Nine studies (Bennell et al., 2016, 2017, 2020; Chen et al., 2020; Jenkinson et al., 2009; Messier et al., 2004; Veenhof et al., 2006; Wang et al., 2016, 2020) had a good methodology, receiving a score greater than six, whilst six studies (Mihalko et al., 2019; Alfieri et al., 2020; Chen et al., 2020; Farr et al., 2010; Focht et al., 2014; Rejeski et al., 2002) had a fair methodology, receiving a score between 4 and 6. One study (Keefe et al., 2004) had a score of three, indicating that the methodological quality was poor. Apart from one study (Focht et al.,

2014), intervention groups were concealed and randomly allocated across the studies. Whilst all studies had easily identifiable eligibility criteria, a baseline comparison between participants was only reported in ten studies (Bennell et al., 2016, 2017, 2020; Chen et al., 2020; Farr et al., 2010; Focht et al., 2014; Jenkinson et al., 2009; Messier et al., 2004; Wang et al., 2016, 2020). Nil studies (Mihalko et al., 2019; Alfieri et al., 2020; Bennell et al., 2016, 2017, 2020; Chen et al., 2020; Farr et al., 2010; Focht et al., 2014; Jenkinson et al., 2009; Keefe et al., 2004; Messier et al., 2004; Veenhof et al., 2006; Wang et al., 2016, 2020; Rejeski et al., 2002; Bokaeian et al., 2021) blinded their therapist or assessors. The Kappa coefficient of inter-rater reliability for this review was 0.88, which can be interpreted as almost perfect (Landis et al.). All studies final agreed score for each PEDro item is reported in Appendix B.

3.3. Study characteristics

This review included 3113 participants with a mean age range of 54–76 years. Allocation of participants was similar between groups, with 1094 individuals assigned to an exercise-only group, whilst 1176

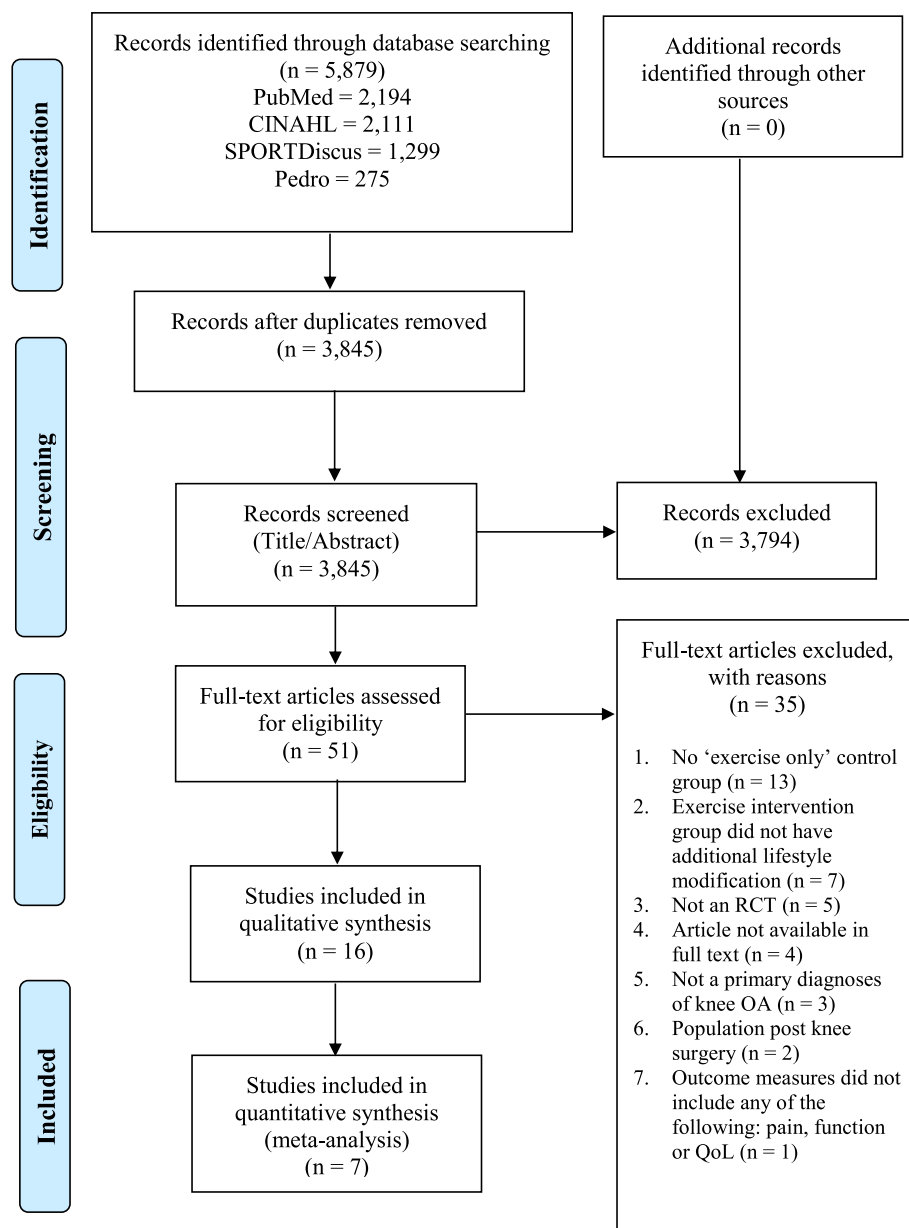


Fig. 1. Flow diagram of included studies.

were assigned to an exercise program with the inclusion of additional lifestyle modifications. All studies included both males and females and of those studies, all reported a higher female population (83.5%) than males. The participant inclusion criteria across all studies required participants to be diagnosed with knee OA and have radiographic evidence of the disease for at least 3–6 months. All studies excluded individuals who had suffered recent knee trauma, presented with a neuromuscular disorder or were seeking adjunct non-exercise forms of treatment. Participant inclusion criteria concerning disease severity were determined by radiographic or criterion-based evidence and the requirements for baseline physical activity levels varied between studies. Full participant eligibility for studies is reported in [Appendix C](#).

3.4. Study interventions

The lifestyle modifications utilised across studies can be broadly categorised into advice and education, dietary modifications, and mind-body exercises. Reported in nine ([Alfieri et al., 2020](#); [Bennell et al., 2017, 2020](#); [Farr et al., 2010](#); [Keefe et al., 2004](#); [Messier et al., 2004](#); [Veenhof et al., 2006](#); [Wang et al., 2020](#); [Rejeski et al., 2002](#)) and 11 ([Alfieri et al., 2020](#); [Bennell et al., 2016, 2017](#); [Chen et al., 2020](#); [Farr et al., 2010](#); [Focht et al., 2014](#); [Jenkinson et al., 2009](#); [Keefe et al., 2004](#); [Messier et al., 2004](#); [Wang et al., 2020](#); [Rejeski et al., 2002](#)) studies respectively, healthy lifestyle guidance on physical activity and minimising harmful activities such as alcohol consumption, alongside disease education were the most frequent form of advice and education to be integrated with an exercise program. Pain coping skills and stress management were utilised across nine studies ([Bennell et al., 2016, 2017](#); [Chen et al., 2020](#); [Farr et al., 2010](#); [Focht et al., 2014](#); [Keefe et al., 2004](#); [Veenhof et al., 2006](#); [Wang et al., 2016, 2020](#)) and goal setting and self-motivation strategies aimed towards weight loss and increasing physical activity levels were utilised in five ([Bennell et al., 2017, 2020](#); [Focht et al., 2014](#); [Keefe et al., 2004](#); [Veenhof et al., 2006](#)). Four studies ([Bennell et al., 2020](#); [Chen et al., 2020](#); [Veenhof et al., 2006](#); [Wang et al., 2016](#)) included adherence monitoring and six studies ([Mihalko et al., 2019](#); [Alfieri et al., 2020](#); [Farr et al., 2010](#); [Jenkinson et al., 2009](#); [Messier et al., 2004](#); [Rejeski et al., 2002](#)) included dietary modifications, which consisted of meal plans, weight-loss programs, and advice on healthy recipes. Mind-body exercises, such as yoga and tai chi, were seen in two studies ([Wang et al., 2016](#); [Bokaeian et al., 2021](#)).

A second intervention group, consisting of lifestyle modifications in isolation, were reported in six studies ([Mihalko et al., 2019](#); [Farr et al., 2010](#); [Jenkinson et al., 2009](#); [Messier et al., 2004](#); [Rejeski et al., 2002](#); [Bokaeian et al., 2021](#)), however, are not included in the results of this review due to not meeting the eligibility criteria of having an exercise component in the protocol. With respect to exercise programs included in this review, all studies investigated an exercise protocol with some form of lower body strength and conditioning component and two ([Chen et al., 2020](#); [Farr et al., 2010](#)) of the 16 studies also incorporated neuromuscular training into their intervention. Across all studies, the average duration per exercise session was greater than 20 min, however, intervention timeframes varied between 4 and 78 weeks. Regarding sample size, the average population consisted of 194 participants, although three studies had less than 100 participants. Full study demographics and methodology of included studies are reported in [Tables 1 and 2](#), respectively.

3.5. Outcomes assessed

Several outcome measures were utilised to assess pain intensity, joint stiffness, quality of life, and self-reported or objective physical function, as shown in [Table 2](#). Summarised results of individual studies are reported in [Table 3](#), with the results of all individual studies reported in full in [Appendix D](#). The results of those studies eligible for pooled synthesis are presented in forest plot [Fig. 2a–d](#). Due to the different outcome measures utilised to assess pain intensity, the standardized mean

difference has been used to express the size of the intervention effect, for all other categories the mean difference has been reported. Lifestyle modifications that were included in the meta-analyses consisted of disease education, lifestyle advice, pain coping strategies, stress management, exercise adherence, goal setting, meal plan, weight loss and healthy recipes.

Patient-reported outcome measures (PROM) were used to assess pain intensity. This included the Western Ontario and McMaster Universities Arthritis Index (WOMAC) – Pain subscale, which was utilised in ten studies ([Mihalko et al., 2019](#); [Alfieri et al., 2020](#); [Bennell et al., 2017](#); [Chen et al., 2020](#); [Farr et al., 2010](#); [Jenkinson et al., 2009](#); [Veenhof et al., 2006](#); [Wang et al., 2016, 2020](#); [Bokaeian et al., 2021](#)), whilst the remaining studies utilised a Numerical Rating Scale (NRS) ([Bennell et al., 2017, 2020](#)), Visual Analogue Scale (VAS) ([Alfieri et al., 2020](#); [Bennell et al., 2016](#); [Veenhof et al., 2006](#); [Bokaeian et al., 2021](#)) and Knee Injury and Osteoarthritis Outcome Score (KOOS) – pain subscale ([Bennell et al., 2020](#)). Nine studies ([Alfieri et al., 2020](#); [Bennell et al., 2016, 2017, 2020](#); [Jenkinson et al., 2009](#); [Keefe et al., 2004](#); [Veenhof et al., 2006](#); [Wang et al., 2016](#); [Rejeski et al., 2002](#)) measured quality of life, including sleep quality, self-efficacy and coping abilities, via administered questionnaires, such as SF-36, AQOL and Arthritis self-efficacy scale. An overall individual's self-reported functional capabilities were measured using the WOMAC – Function subscale, which was utilised in seven studies ([Mihalko et al., 2019](#); [Alfieri et al., 2020](#); [Bennell et al., 2016, 2017](#); [Jenkinson et al., 2009](#); [Veenhof et al., 2006](#); [Wang et al., 2016](#)), as well as the KOOS-function subscale ([Bennell et al., 2020](#)). Objective physical function was measured across ten studies ([Mihalko et al., 2019](#); [Bennell et al., 2016](#); [Chen et al., 2020](#); [Focht et al., 2014](#); [Keefe et al., 2004](#); [Messier et al., 2004](#); [Veenhof et al., 2006](#); [Wang et al., 2016, 2020](#); [Bokaeian et al., 2021](#)). Assessments included timed up-and-go (TUG), quadriceps strength, stair climb ability and various forms of walking tests examining gait speed and distance travelled. Moderate and vigorous physical activity level was recorded in two studies ([Farr et al., 2010](#); [Focht et al., 2014](#)). Regarding knee joint stiffness the WOMAC – Stiffness subscale was utilised in three studies ([Alfieri et al., 2020](#); [Chen et al., 2020](#); [Wang et al., 2016](#)).

3.6. Pain intensity

All studies ([Mihalko et al., 2019](#); [Alfieri et al., 2020](#); [Bennell et al., 2016, 2017, 2020](#); [Chen et al., 2020](#); [Farr et al., 2010](#); [Jenkinson et al., 2009](#); [Keefe et al., 2004](#); [Messier et al., 2004](#); [Veenhof et al., 2006](#); [Wang et al., 2016, 2020](#); [Bokaeian et al., 2021](#)) measuring pain reported significant improvements post-intervention within all groups, of which, six studies ([Chen et al., 2020](#); [Keefe et al., 2004](#); [Messier et al., 2004](#); [Wang et al., 2016, 2020](#); [Bokaeian et al., 2021](#)) reported improvements to be greater following the inclusion of lifestyle modifications compared to exercise in isolation. In contrast, pain improvements were seen within the exercise in isolation group for only one study ([Farr et al., 2010](#)). Pooled analysis of seven studies ([Bennell et al., 2016, 2017, 2020](#); [Chen et al., 2020](#); [Messier et al., 2004](#); [Veenhof et al., 2006](#); [Wang et al., 2020](#)) ($n = 966$) for pain intensity ([Fig. 2a](#)) at varying time points between 12 weeks and six months demonstrated a reduction in pain scores (SMD -0.68 [95% CI -1.26 to -0.10]; $I^2 = 95\%$), favouring the inclusion of additional lifestyle modifications to a traditional exercise program.

3.7. Joint stiffness

Significant improvements within both groups were reported amongst all studies ([Alfieri et al., 2020](#); [Chen et al., 2020](#); [Wang et al., 2016, 2020](#)) that assessed joint stiffness, however, three studies ([Chen et al., 2020](#); [Wang et al., 2016, 2020](#)) reported benefits to be greater with the inclusion of lifestyle modifications compared to exercise alone. Among the two eligible studies ([Chen et al., 2020](#); [Wang et al., 2020](#)) ($n = 350$), this was further supported by a pooled analysis of the WOMAC - Stiffness subscale ([Fig. 2b](#)), which demonstrated a point difference of MD -0.69

Table 2
Study methodology.

Author, Year	Lifestyle modifications included	Intervention duration (Weeks)	Functional Outcome Measure(s)	Measurement tool	Assessment timing (weeks)
Alfieri et al., 2020	Disease education Lifestyle advice Pain coping strategies Healthy recipes	8	1. Pain 2. Self-reported function 3. Joint stiffness 4. QoL 5. Pain tolerance	1a. VAS 1 b. WOMAC Pain 2. WOMAC function 3. WOMAC joint stiffness 4. FANTASTICO 5. Pressure pain tolerance threshold – PPT	Baseline 8
Bennell et al., 2016	Disease education Pain-coping strategies Stress management	12	1. Pain 2. Self-reported function 3. QoL 4. Physical function	1. VAS 2. WOMAC function 3. Coping strategy questionnaire – Pain coping 4a. Quadricep strength 4 b. 30s STS 4c. 20 m step-test	Baseline 12 32 52
Bennell et al., 2017	Disease education Lifestyle advice Pain coping strategies Stress management Goal setting	24	1. Pain 2. Self-reported function 3. QoL	1a. NRS 1 b. WOMAC – pain 2. WOMAC – function 3. AQoL	Baseline 36 52 72
Bennell et al., 2020	Lifestyle advice Goal setting Exercise adherence	24	1. Pain 2. Self-reported function 3. QoL	1a. NRS 1 b. KOOS pain 2. KOOS function 3a. KOOs QoL 3 b. AQoL	Baseline 24
Bokaeian et al., 2021	Yoga	4	1. Pain 2. Physical function 3. Gait biomechanics	1a. VAS 1b. WOMAC pain 2.2 m walk-test (distance) 3. 2 m walk-test (gait speed)	Baseline 4 8
Chen, 2019	Disease education Pain coping strategies Stress management Exercise adherence	24	1. Pain 2. joint stiffness 3. Physical function	1a. NRS 1b. WOMAC Pain 2. WOMAC stiffness 3a. 5× STS 3. TUG	Baseline 12 24
Farr et al., 2010	Disease education Lifestyle advice Pain coping skills Stress management Healthy recipes	36	1. Pain 2. Physical activity level	1. WOMAC pain 2a. Moderate PA level 2 b. Vigorate PA level	Baseline 12 36
Focht et al., 2014	Disease education Pain coping strategies Stress management Goal setting	12	1. Physical function 2. Physical activity level	1.400-m walk time 2. Total weekly PA time	Baseline 12 52
Jenkinson et al., 2009	Disease education Meal Plan Weight-loss Healthy recipes	104	1. Pain 2. Self-reported unction 3. QoL	1. WOMAC – Pain 2. WOMAC – function 3. SF-36	Baseline 24 52 104
Keefe et al., 2004	Lifestyle advice Pain coping strategies Goal setting	12	1. Physical function 3. QoL	1. VO2K 2a. The Arthritis Self-Efficacy Scale 2 b. Coping strategy questionnaire	Baseline 12
Messier et al., 2004	Disease education Lifestyle advice Meal plan Weight-loss Healthy recipes	72	1. Pain 2. Physical function	1. WOMAC Pain 2a. 6 min walk-test 2 b. Stair climb	Baseline 24 72
Mihalko, 2018	Meal plans Calorie restriction	72	1. Pain 2. Physical function 3. Self-reported function	1. WOMAC pain 2a. 6 min walk-test 2b. Gait speed 3. WOMAC function	Baseline 24 72
Rejeski et al., 2002	Disease education Lifestyle advice Meal plans Weight-loss	72	1. QoL	1a. SF-36 mental health 1b. SF-36 physical health 1c. SF-36 satisfaction w/function 1d. SF-36 satisfaction w/appearance	Baseline 24 72
Veenhof et al., 2006	Disease education Lifestyle advice Pain coping strategies Stress management Goal setting Adherence monitoring	65	1. Pain 2. Self-reported function 3. Physical function 4. QoL	1a. VAS 1b. WOMAC Pain 2. WOMAC Function 3.5 m walk test 4. SF-36	Baseline 13 39 65
Wang et al., 2016	Stress monitoring Adherence monitoring Tai Chi	12	1. Pain 2. Self-reported function 3. Physical function 4. QoL 5. Joint stiffness	1a. WOMAC pain 1b. NSAID consumption 1c. Analgesic consumption 2. WOMAC function 3a. 6 min walk test	Baseline 12 24 52

(continued on next page)

Table 2 (continued)

Author, Year	Lifestyle modifications included	Intervention duration (Weeks)	Functional Outcome Measure(s)	Measurement tool	Assessment timing (weeks)
Wang et al., 2020	Disease education Lifestyle advice Pain coping strategies Stress management	24	1. Pain 2. Joint stiffness 3. Physical function	3b. 20 m walk test 4a. Patient Global Assessment score 4b. Beck Depression inventory-II 4c. SF-36 4d. Arthritis self-efficacy scale 5. WOMAC stiffness 1. WOMAC pain 2. WOMAC stiffness 3a. Five-times-sit-to-stand-test (FTSST) 3b. Timed up and go (TUG)	Baseline 24 48

AQoL Assessment of Quality of Life, KOOS Knee Injury and Osteoarthritis Outcome Score, NRS Numerical rating scale, PPT Pain pressure threshold, PA Physical activity, QoL Quality of life, STS Sit-to-stand, TUG Timed up-and-go, VAS Visual Analogue Scale, WOMAC Western Ontario and McMaster Universities Osteoarthritis, NSAID Non-steroidal anti-inflammatory drug.

Table 3

Results of individual studies.

Author, Year	Outcome measures				
	Pain	Self-reported function	Objective Physical function	Joint stiffness	Quality of life
Alfieri et al., 2020	=	=	=	=	=
Bennell et al., 2016	=	✓	✓	NA	=
Bennell et al., 2017	=	=	NA	NA	=
Bennell et al., 2020	=	=	NA	NA	✓
Bokaeian et al., 2021	✓	NA	=	NA	✓
Chen, 2019	✓	NA	✓	✓	✓
Farr et al., 2010	x	NA	NA	NA	NA
Focht et al., 2014	NA	NA	=	NA	NA
Jenkinson et al., 2009	=	=	NA	NA	✓
Keefe et al., 2004	✓	NA	✓	NA	✓
Messier et al., 2004	✓	NA	✓	NA	NA
Mihalko, 2018	=	=	✓	NA	✓
Rejeski et al., 2002	NA	NA	NA	NA	✓
Veenhof et al., 2006	=	=	✓	NA	=
Wang et al., 2016	✓	✓	=	✓	=
Wang et al., 2020	✓	NA	✓	✓	NA

✓favours exercise with lifestyle modifications over exercise alone; = no additional benefits seen with the inclusion of lifestyle modifications to exercise; X favours exercise in isolation over exercise with the inclusion of lifestyle modifications, NA not assessed.

([95% CI -1.21, -0.17]; I² = 0%) at six months, indicating that the addition of lifestyle modifications had a significant positive effect on joint stiffness.

3.8. Quality of life

All studies (Mihalko et al., 2019; Alfieri et al., 2020; Bennell et al., 2016, 2017, 2020; Chen et al., 2020; Jenkinson et al., 2009; Keefe et al., 2004; Veenhof et al., 2006; Wang et al., 2016; Rejeski et al., 2002; Bokaeian et al., 2021) measuring quality of life demonstrated significant improvements post-intervention within the control and experimental groups, of which, seven (Mihalko et al., 2019; Chen et al., 2020;

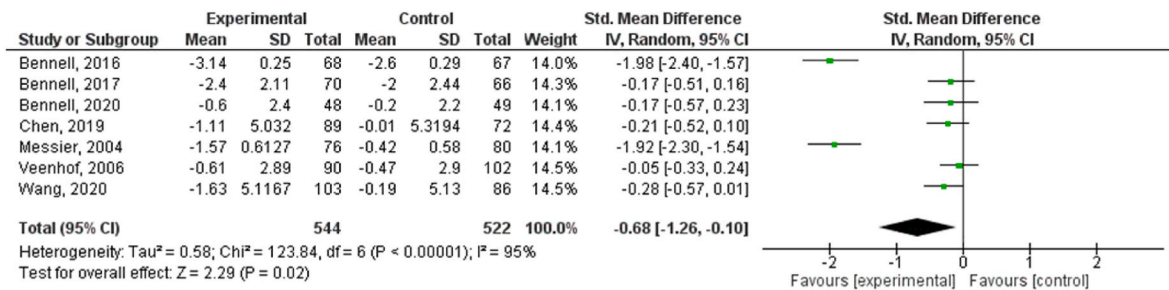
Jenkinson et al., 2009; Keefe et al., 2004; Rejeski et al., 2002; Bokaeian et al., 2021) reported improvements to be greater following the inclusion of lifestyle modifications compared to exercise alone. However, pooled analysis of the two eligible studies (Bennell et al., 2017, 2020) (n = 233) seen in Fig. 2c demonstrated nil additional benefits of including lifestyle modifications with exercise in an individual’s self-reported QoL (MD -0.10 ([95% CI -0.24, 0.04]; I² = 0%) at six months.

3.9. Physical function

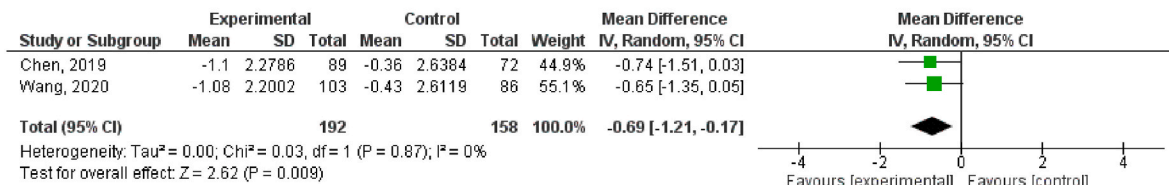
With the exception of three studies (Focht et al., 2014; Wang et al., 2016; Bokaeian et al., 2021), all studies (Mihalko et al., 2019; Bennell et al., 2016; Chen et al., 2020; Focht et al., 2014; Keefe et al., 2004; Messier et al., 2004; Veenhof et al., 2006; Wang et al., 2016, 2020; Bokaeian et al., 2021) measuring self-reported and objective physical function reported significant improvements in favour of the addition of lifestyle modifications to exercise alone post-intervention. For the two studies (Chen et al., 2020; Wang et al., 2020) eligible for pooled analysis (n = 350) (Fig. 2d), overall improvements in timed up-and-go speed were (MD -1.26 s ([95% CI -1.34, -1.17]; I² = 0%) at six months, which indicates that the inclusion of lifestyle modifications had a significant positive effect on objective physical function and walk speed. Significant improvements within the control and experimental groups were reported consistently throughout all studies (Mihalko et al., 2019; Alfieri et al., 2020; Bennell et al., 2016, 2017, 2020; Jenkinson et al., 2009; Veenhof et al., 2006; Wang et al., 2016) measuring self-reported function. As assessed by changes in self-reported outcome measure scores, improvements favouring the inclusion of lifestyle modifications compared to exercise alone were seen in two studies (Bennell et al., 2016; Wang et al., 2016).

3.10. Grading the evidence

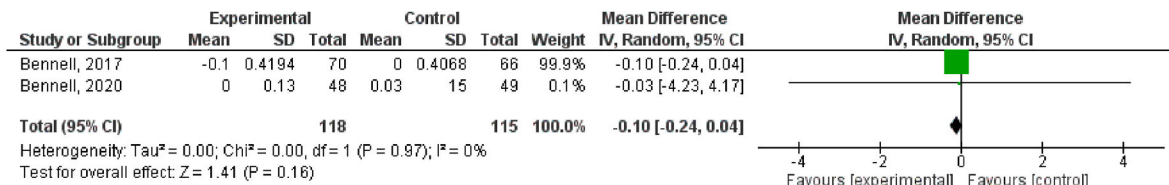
The GRADE certainty of evidence rating and rationale for each meta-analysis result is detailed in Appendix E. A high certainty of evidence was retained for reduction in knee joint stiffness favouring the addition of lifestyle modifications (MD -0.69 [95% CI -1.21, -0.17]; I² = 0%). For the improvements seen in physical function with the addition of lifestyle modifications (MD -1.26 s ([95% CI -1.34, -1.17]; I² = 0%).) we found a moderate certainty of evidence (downgraded one point for imprecision). For the decrease in pain intensity with the addition of lifestyle modifications (SMD -0.68 [95% CI -1.26 to -0.10]; I² = 95%).) we found a low certainty of evidence (downgraded by three points for evidence of indirectness, inconsistency, and imprecision). Finally, a moderate certainty of evidence for the nil additional benefits seen when including lifestyle modifications for quality of life improvements (MD -0.10 ([95% CI -0.24, 0.04]; I² = 0%).) as this result was downgraded one point for indirectness.



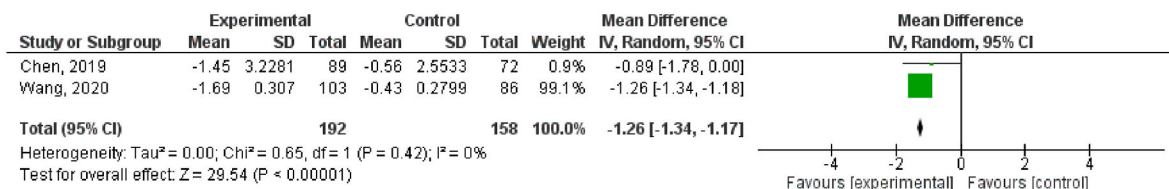
a. Pain intensity at 6-12 weeks – VAS, WOMAC Pain, NRS (41-44, 49, 50, 52)



b. Knee joint stiffness at 6 months – WOMAC stiffness score (44, 52)



c. Quality of life at 6 months – AQoL score (42, 43)



d. Objective Physical function at 6 months – Timed up and go speed (44, 52)

Fig. 2. (a-d). Meta-analysis results for eligible outcomes (*p < 0.05).

4. Discussion

Guidelines from professional medical organisations (Bannuru et al., 2019; Fernandes et al., 2013; Kolasinski et al., 2019; RACGP, 2018; Bruyère et al.) recommend that non-surgical, non-pharmacological interventions should consist of exercise with the inclusion of other lifestyle modifications in the treatment of individuals with knee OA. There is likely a positive interaction between exercise and lifestyle modifications meaning the combined effects of both treatments are greater than their individual effects, indicating potential synergy. The findings of this systematic review and meta-analysis support the addition of lifestyle modifications to a traditional exercise program in the management of knee OA, of which advice & education consisting of disease management and self-care strategies, were found to be the most effective in reducing pain and improving function.

In line with past evidence, findings from this review have

demonstrated that the inclusion of lifestyle modifications can lead to greater reductions in self-reported pain compared to exercise in isolation (Chen et al., 2020; Keefe et al., 2004; Messier et al., 2004; Wang et al., 2016, 2020; Bokaeian et al., 2021). Increasing understanding and tolerance towards pain through educational workshops consisting of pain-coping strategies and stress management would appear to reduce pain intensity in individuals diagnosed with knee OA (Keefe et al.; Keefe et al., 1990; Lee et al., 2017). This was evident in the Alfieri et al. (2020) study, which reported a greater increase in pain pressure threshold across lower-limb muscles following the inclusion of an 8-week pain coping strategy workshop, compared to an isolated exercise program. It has also been suggested that pain reductions following the inclusion of lifestyle modifications may also be stemmed from improved gait mechanics (Bliddal et al., 2014; Robson et al.). Subsequent to weight loss, reductions in joint loading force during heel strike may also reduce pain and prevent further degeneration of the articular cartilage within the

knee joint. This was evident among studies (Jenkinson et al., 2009; Messier et al., 2004) with dietary modifications consisting of a weight loss program, meal plans and dietary advice, which reported significant pain reductions following an 8–12-week protocol. Moreover, given the relationship between inflammation and pain, a decrease in inflammatory biomarkers associated with weight loss, such as CRPM and IL-6, could also be associated with reducing pain (Loeser et al., 2017).

Although pain reductions favouring the inclusion of lifestyle modifications were demonstrated in our pooled analysis (Fig. 2a.), the minimally clinically important differences for pain intensity could not be determined due to the variation in outcome measures included. Therefore, it is possible that the pain reductions following the inclusion of lifestyle modifications compared to exercise alone, although significant, may not necessarily translate to clinical meaningfulness. Given the small number of studies currently eligible for meta-analysis in this review, contributions from future research may confer clinical meaningfulness for pain-related outcomes.

Improvements in self-reported and objective physical function favouring the inclusion of lifestyle modifications were reported across ten studies (Mihalko et al., 2019; Bennell et al., 2016; Chen et al., 2020; Focht et al., 2014; Keefe et al., 2004; Messier et al., 2004; Veenhof et al., 2006; Wang et al., 2016, 2020; Bokaeian et al., 2021). Given the findings of studies (Chen et al., 2020; Focht et al., 2014; Keefe et al., 2004; Veenhof et al., 2006; Wang et al., 2016, 2020) that incorporated interventions consisting of disease education, lifestyle advice, and goal setting, it could be suggested that additional functional improvements are associated with alterations to exercise habits. Consequential of an increase in awareness surrounding the benefits of exercise, this was evident in four studies (Chen et al., 2020; Farr et al., 2010; Focht et al., 2014; Veenhof et al., 2006), which reported significant increases in exercise adherence and physical activity level, and therefore, physical function. This positive correlation between physical activity levels and functional outcomes is further supported by past literature (Kraus et al.; Chang et al.; Escalante et al.), which reported improvements in 6-min walk tests and stair climb time following interventions involving various land based and aquatic exercises.

Consistent with our pooled analysis results on self-reported pain (Fig. 2a), improvements in physical function may also be attributed to greater pain tolerance (Moss et al.). This was supported by the results of our pooled analysis for physical function (Fig. 2d), where a minimum clinically important difference in speed for the TUG outcome was seen in favour of the intervention group (Alghadir et al.). Furthermore, considering the correlation between self-efficacy and functional status (Kuru Çolak et al.; Maly et al.), it could be argued that an increase in self-efficacy level following telephone coaching sessions that revolve around self-motivation and goal setting could augment functional gains. This was evident in Bennell's et al. (2017) study, which reported additional improvements in self-reported and objective physical function following a six-month protocol. Increased energy levels consequent of improved sleep quality due to greater pain tolerance and stress management following the inclusion of lifestyle modifications, may have also contributed to the additional functional benefits seen (Sariyildiz et al.).

Mind-body exercises, such as yoga and tai-chi, can be a complement to traditional exercise options for individuals with knee OA. Unlike previous research (Fransen et al., 2015), which found yoga to be less beneficial and effective compared to traditional exercise protocols, a study included in this review reported improvements in pain and function following 4-weeks of yoga to be superior compared to exercise in isolation (Bokaeian et al., 2021). This could potentially be explained by the multi-factorial effects of reductions in joint stiffness, stress and anxiety associated with yoga (Cheung et al.; Haaz and Bartlett). Despite the findings reported in the Wang et al. (2016) study, there is still a body of strong evidence supporting the inclusion of tai-chi in the management of knee OA (Ye et al., 2014; Wang et al., 2009). Consequent to central nervous system factors, including the activation of neuroendocrine and

autonomic functioning systems, as well as directing neuro-chemical and analgesic pathways, tai-chi can regulate inflammatory responses, and thus, can reportedly also reduce pain (Ye et al., 2014).

There were several strengths to this review, which included the wide range of lifestyle modifications utilised, the overall good methodological quality rating of included studies, as well as, a moderate to high certainty of evidence rating for most meta-analysis outcomes. However, some limitations should also be noted, one of which was the clinical heterogeneity across the included studies, attributed to varying intervention design characteristics which restricted pooled synthesis of results to seven eligible studies. The assessment time points and follow-up periods also varied which meant conclusions on the influence of lifestyle modifications to an exercise program in the longer term were not possible. With respect to heterogeneity within the meta-analysis studies, a random effects model of analysis was applied in an attempt to mitigate any intervention protocol differences, and despite the study design variations, positive effects were seen across the majority of outcomes eligible for meta-analysis. An example of this, was although QoL outcomes significantly favoured the addition of lifestyle modifications over exercise alone in seven out of 12 studies, only two studies met the eligibility criteria for meta-analysis, which may explain the lack of significance found for this result.

A further possible limitation of this review was that 10 studies utilised home exercise programs (HEP) in their study design. With no gold standard to measure exercise adherence and under-reporting of this, accurate measurement of exercise adherence to a HEP remains a challenge. Finally, whilst lifestyle modifications have been linked to various mental health benefits that are unrelated to OA-induced impairments (Lasikiewicz et al., 2014; Janssen et al.; Sheehan et al.), most studies included in this review have only measured the effects of lifestyle modifications in the form of physical benefits, with only a few reporting on psychological variables. Therefore, the mental health benefits of lifestyle modification may have been underestimated.

5. Conclusion

The results of this systematic review and meta-analysis provide support to guidelines suggesting the inclusion of additional lifestyle modifications to a traditional exercise program for improvements in pain intensity, stiffness and physical function amongst individuals with knee OA. Individual results showed improvements in quality of life with the addition of lifestyle modifications, however, this was not demonstrated in the pooled analysis. Although greater benefits were seen with the addition of lifestyle modifications in 12 out of the 16 studies, heterogeneity of individual study methodology limited eligibility for meta-analysis. For those studies included in meta-analyses, the addition of lifestyle modifications (disease education, lifestyle advice, pain-coping, self-management strategies and adherence monitoring) to a traditional exercise program had the most positive impact on outcomes. Future research should compare the effectiveness of the different lifestyle modification types reported in this review, in conjunction with exercise for the management of knee OA, along with further exploration of the associated mental health benefits.

Funding

The authors have no funding to declare.

Authors' contributions

Authors (L.S, A.K) have made substantial contributions to all of the following: (1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted. Authors (C.V, W.H) have made substantial contributions the following: (1) the conception and design of the

study and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted.

request from the corresponding author [L.S]. The data are not publicly available due to being stored in a secured cloud-based server.

Availability of data and materials'

The data that support the findings of this study are available on

Declaration of competing interest

The authors declare that they have no competing interests.

Abbreviations

- AQoL Assessment of Quality of Life
- F Female
- OA osteoarthritis
- KOOS Knee Injury Osteoarthritis Outcome Score
- GRADE Grading of Recommendation Assessment, Development, and Evaluation
- M Male
- NA Not assessed
- NRS Numerical Pain Rating Scale
- NSAID Non-steroidal anti-inflammatory drug
- PA Physical Activity
- PPT Pain Pressure Threshold
- PRISMA Preferred Reporting Items for Systematic Reviews and Meta-Analyses
- PROMs Patient reported outcome measures
- QoL Quality of life
- RCT Randomised controlled trial
- SD Standard Deviation
- STS Sit-to-stand
- TUG Timed up and go
- VAS Visual analogue scale
- WOMAC Western Ontario and McMaster Universities Osteoarthritis

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.msksp.2023.102858>.

Appendix A. Database search strategies

Database	Search strategy
PubMed	(osteoarthr*[Title/Abstract] OR degenerative [Title/Abstract]) AND (knee*[Title/Abstract]) AND (exercis*[Title/Abstract] OR physiotherap*[Title/Abstract] OR "physical therap*" OR rehab*[Title/Abstract]) AND ("randomized controlled trial" [Publication Type] OR "controlled clinical trial" [Publication Type] OR randomized [Title/Abstract] OR placebo [Title/Abstract] OR randomly [Title/Abstract] OR trial [Title/Abstract] OR groups [Title/Abstract] OR multi.modal [All Fields]) AND "humans" [MeSH Terms:noexp]
CINAHL	((TI osteoarthr* OR AB osteoarthr*) OR (TI degenerative OR AB degenerative)) AND ((TI knee* OR AB knee*)) AND ((TI exercis* OR AB exercis*) OR (TI physiotherap* OR AB physiotherap*)) OR "physical therap*" AND ("randomized controlled trial [Publication Type]" OR "controlled clinical trial [Publication Type]" OR (TI randomized OR AB randomized) OR (TI placebo OR AB placebo) OR (TI randomly OR AB randomly) OR (TI trial OR AB trial) OR (TI groups OR AB groups) OR multi.modal)
SPORTDiscus	((TI osteoarthr* OR AB osteoarthr*) OR (TI degenerative OR AB degenerative)) AND ((TI knee* OR AB knee*)) AND ((TI exercis* OR AB exercis*) OR (TI physiotherap* OR AB physiotherap*)) OR "physical therap*" AND ("randomized controlled trial [Publication Type]" OR "controlled clinical trial [Publication Type]" OR (TI randomized OR AB randomized) OR (TI placebo OR AB placebo) OR (TI randomly OR AB randomly) OR (TI trial OR AB trial) OR (TI groups OR AB groups) OR multi.modal)
Pedro	Knee AND osteoarthritis AND exercise AND treatment

Appendix B. Pedro critical appraisal score

PEDro Critical Appraisal Scale												
Author (yr)	Q1	Q2	Q3	Q4	Q5	Q6	Q6	Q7	Q8	Q9	Q10	PEDRO SCORE
Alfieri et al., 2020	Y	Y	Y	N	Y	N	N	Y	N	Y	Y	6/10
Bennell et al., 2016	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	7/10
Bennell et al., 2017	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	8/10
Bennell et al., 2020	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	9/10
Bokaeian et al., 2021	Y	Y	Y	N	Y	N	N	Y	Y	Y	Y	7/10
Chen 2019	Y	Y	Y	Y	Y	N	N	N	Y	N	Y	6/10
Farr												

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PEDro Critical Appraisal Scale												
Author (yr)	Q1	Q2	Q3	Q4	Q5	Q6	Q6	Q7	Q8	Q9	Q10	PEDRO SCORE
2010	Y	Y	Y	Y	Y	N	N	N	N	N	Y	5/10
Focht et al., 2014	Y	N	Y	Y	Y	N	N	Y	N	Y	Y	6/10
Jenkinson et al., 2009	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	7/10
Keefe et al., 2004	Y	Y	Y	N	N	N	N	N	N	N	Y	3/10
Messier et al., 2004	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	8/10
Mihalko 2018	Y	Y	Y	N	Y	N	N	Y	Y	N	Y	6/10
Rejeski et al., 2002	Y	Y	Y	N	Y	N	N	Y	N	Y	Y	6/10
Veenhof et al., 2006	Y	Y	Y	N	Y	N	N	Y	Y	Y	Y	7/10
Wang et al., 2016	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	7/10
Wang et al., 2020	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	7/10

Appendix C. Participant inclusion and exclusion criteria within the included studies

Author, Year	Inclusion Criteria	Exclusion Criteria
Alfieri et al., 2020	<ul style="list-style-type: none"> Older than 50 years of age presented clinical and radiographic diagnosis of unilateral or bilateral knee OA Kellgren-Lawrence grading scale 1 to 4 Pain perception equal to or above 4 cm in visual analogue scale (VAS) 	<ul style="list-style-type: none"> Patients with any other chronic diseases such as fibromyalgia, rheumatoid arthritis, neurologic or cardiac diseases and uncontrolled hypertension
Bennell et al., 2016	<ul style="list-style-type: none"> Ages over 50 years knee OA fulfilling the American College of Rheumatology criteria knee pain for 3+ months Average pain during previous week of 40+ on 100-mm visual analogue scale (VAS) Moderate difficulty with daily activities (WOMAC) 	<ul style="list-style-type: none"> Systemic arthritic condition Self-reported history of serious mental illness; neurological Knee surgery within the past 6 months or total joint replacement Awaiting or planning any back or lower limb surgery Current or past oral or intra-articular corticosteroid use Physiotherapy, chiropractic or acupuncture treatment or exercises specifically for the knee Walking exercise; participating in a regular exercise Participating in or previous participation in a formal PCST program Inability to walk unaided Inability to safely participate in moderate-intensity exercise Undertaking regular lower-extremity strengthening exercises or receiving non-drug management for knee pain from a health professional Knee surgery or intraarticular corticosteroid injection Systemic arthritic conditions or current or past Other condition affecting lower-extremity function Unable to use/access a telephone Score of >21 (Depression, Anxiety and Stress Scale) Lateral ≥ medial joint space narrowing on x-ray Knee surgery/joint injection Current or past oral corticosteroids use Systemic arthritic conditions Other condition affecting lower limb function Participation in knee strengthening or neuromuscular/functional exercise Unable to walk unaided Systemic arthritis, diabetes, neuromuscular diseases Injection in the lower-extremity joints Hip or knee replacement Recent trauma to the knee joint Body mass index >35 History of lower-extremity surgery
Bennell et al., 2017	<ul style="list-style-type: none"> Age >50 years Average knee pain >4 on an 11-point numeric rating scale American College of Rheumatology clinical criteria for knee OA Classification as sedentary or insufficiently physically active according to the Active Australia Survey 	<ul style="list-style-type: none"> Systemic arthritic conditions or current or past Other condition affecting lower-extremity function Unable to use/access a telephone Score of >21 (Depression, Anxiety and Stress Scale) Lateral ≥ medial joint space narrowing on x-ray Knee surgery/joint injection Current or past oral corticosteroids use Systemic arthritic conditions Other condition affecting lower limb function Participation in knee strengthening or neuromuscular/functional exercise Unable to walk unaided Systemic arthritis, diabetes, neuromuscular diseases Injection in the lower-extremity joints Hip or knee replacement Recent trauma to the knee joint Body mass index >35 History of lower-extremity surgery
Bennell et al., 2020	<ul style="list-style-type: none"> Aged ≥50 years Knee pain on most days of the past month Knee pain for ≥3 months Average overall pain severity ≥4 (NRS) Tibiofemoral osteophytes on x-ray Obesity (BMI ≥30 kg/m²) Own a mobile phone with text messaging 	<ul style="list-style-type: none"> Systemic arthritic conditions Other condition affecting lower limb function Participation in knee strengthening or neuromuscular/functional exercise Unable to walk unaided Systemic arthritis, diabetes, neuromuscular diseases Injection in the lower-extremity joints Hip or knee replacement Recent trauma to the knee joint Body mass index >35 History of lower-extremity surgery
Bokaician et al., 2021	<ul style="list-style-type: none"> 45–76 years of age Knee pain of 30 or greater on the 100-mm visual analogue scale (VAS) Unilateral or bilateral tibiofemoral joint OA of grades 2–3 (Kellgren–Lawrence grading system) History of pain for more than a month, and ability to walk without assistive devices 	<ul style="list-style-type: none"> Systemic arthritis, diabetes, neuromuscular diseases Injection in the lower-extremity joints Hip or knee replacement Recent trauma to the knee joint Body mass index >35 History of lower-extremity surgery
Chen, 2019	<ul style="list-style-type: none"> ≥60 years old Experiencing knee pain on most days within the past month Knee pain between 3 and 7 (NRS) Intact cognitive functioning (Short Portable Mental Status Questionnaire) 	<ul style="list-style-type: none"> Joint replacement or arthroscopic surgery on the affected side of the knee Other health issues that could induce adverse events Already having other regular exercise habits
Farr et al., 2010	<ul style="list-style-type: none"> Age between 35 and 68 years Pain on 4 or more days of the week in one or both knees for at least 4 months during the previous year Less than 5 years' symptom duration Radiographic status of grade II OA (and no higher) in at least one knee (Kellgren and Lawrence) Disability due to knee OA (WOMAC) 	NR
Focht et al., 2014	<ul style="list-style-type: none"> 0 min/week of structured exercise during the prior 6 months Self-reported difficulty in simple functional tasks Radiographic evidence of Kellgren-Lawrence scale stage II or III (mild to moderate) tibiofemoral OA Willingness to participate in our study protocol. 	<ul style="list-style-type: none"> Serious medical conditions Inability to walk unaided Physician-documented radiographic evidence of knee joint varus or valgus malalignment OA severity >3 on the Kellgren-Lawrence scale Rheumatoid arthritis Intra-articular injection Total knee replacement
Jenkinson et al., 2009	<ul style="list-style-type: none"> All men and women aged 45 and over with a body mass index (BMI) of ≥28.0 Knee pain 	<ul style="list-style-type: none"> OA severity >3 on the Kellgren-Lawrence scale Rheumatoid arthritis Intra-articular injection Total knee replacement

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Author, Year	Inclusion Criteria	Exclusion Criteria
Keefe et al., 2004	NR	<ul style="list-style-type: none"> Comorbid medical conditions that could affect their health status over the course of the trial
Messier et al., 2004	<ul style="list-style-type: none"> Age 60 years Body mass index 28 kg/m² Persistent knee pain Sedentary activity pattern Self-reported difficulty in daily functional tasks Radiographic evidence of grade I–III tibiofemoral or patellofemoral OA 	<ul style="list-style-type: none"> Comorbid medical conditions that could affect their health status/ability to take part in trial Mini-Mental State Examination score of 24 Inability to walk un-aided Inability to complete the protocol, in the opinion of the clinical staff, because of frailty, illness, or other reasons
Mihalko, 2018	<ul style="list-style-type: none"> Grade II–III (mild to moderate) radiographic tibiofemoral OA or tibiofemoral plus patellofemoral OA Persistent knee pain 27.0 ≤ BMI ≤ 41 kg/m² Sedentary lifestyle (less than 30 min of formal exercise per week) 	<ul style="list-style-type: none"> Significant comorbid disease that prevented safe participation in an exercise program Significant cognitive impairment or depression
Rejeski, 2010	<ul style="list-style-type: none"> 60+ years BMI 28+ Persistent knee pain Sedentary activity pattern Self-reported difficulty in performing functional activities Radiographic evidence of tibio-femoral osteoarthritis Willingness to undergo testing and intervention procedures OA of the hip or knee according to the clinical criteria of the American College of Rheumatology (ACR) 	<ul style="list-style-type: none"> Comorbidity that prevented safe participation in an exercise program Mini-Mental score 24+ Inability to walk unaided Inability to complete the protocol, in the opinion of the clinical staff, because of frailty, illness, or other reasons.
Veenhof et al., 2006	<ul style="list-style-type: none"> OA of the hip or knee according to the clinical criteria of the American College of Rheumatology (ACR) 	<ul style="list-style-type: none"> Indication for hip or knee replacement within 1 year Contraindication for exercise therapy Low level of physical function Had undertaken Tai Chi or PT in the past year Presenting with serious medical conditions Use of articular injections in the past 3 or 6 months History of knee surgery
Wang et al., 2016	<ul style="list-style-type: none"> Age ≥ 40 years American College of Rheumatology criteria for symptomatic KOA Radiographic evidence of KOA Score of 40 or greater on at least 1 of 5 questions in the WOMAC pain subscale range 	<ul style="list-style-type: none"> History of knee surgery Severe deformity of the lower limbs (e.g., knee varus or valgus) Comorbidity that could induce adverse events during trial
Wang et al., 2020	<ul style="list-style-type: none"> Age ≥ 60 years Persistent knee pain (3–7/11 in NPRS) Intact cognitive functioning (Short Portable Mental Status Questionnaire) 	

Appendix D. Results of Individual Studies

Author, Year	Functional Outcome Measure(s)	Results			
		Timepoint	Control Mean ± SD	Intervention Mean ± SD	
Alfieri et al., 2020	(Bennell and Hinman, 2011) VAS (Hawker et al.) WOMAC Pain (Vitaloni et al.) WOMAC function (Fransen et al., 2015) WOMAC joint stiffness (Stewart) FANTASTICO	1a.	1a. 6.7 ± 1.6	1a. 6.8 ± 1.9	
		Baseline	1b. 5.5 ± 2.3	1b. 4.7 ± 3.4	
		1b. 8/52	2a. 48.1 ± 18.6	2a. 55.2 ± 26.1	
		2a.	2b. 43.5 ± 21.1	2b. 41.8 ± 28	
		Baseline	3a. 38.7 ± 19.2	3a. 42.1 ± 28.0	
		2b. 8/52	3b. 35.2 ± 18.6	3b. 38.4 ± 30.9	
		3a.	4a. 37.7 ± 21.9	4a. 45.4 ± 28.5	
		Baseline	4b. 478.0 ± 19.1	4b. 43.7 ± 29.3	
		3b. 8/52	5a. 66.3 ± 7.8	5a. 72/6 ± 11.3	
		4a.	5b. 74.2 ± 9.7	5b. 77.3 ± 11.4	
		Baseline			
		4b. 8/52			
		5a.			
		Baseline			
		5b. 8/52			
Bennell et al., 2016	(Bennell and Hinman, 2011) VAS (0–100) (Hawker et al.) WOMAC function (0–68) (Vitaloni et al.) Coping strategy questionnaire – Pain coping (0–163) (Fransen et al., 2015) Quadriceps strength (NM) (Stewart) 30s STS (Cross et al.) 20 m walk-test (m/s)	1a.	1a. 59.1 ± 12/4	Intervention A	Intervention B (Ex + PCST)
		Baseline	1b. 31.8 ± 22.3	(PCST)	
		1b. 12/52	1c. 36 ± 24.6	1a. 58.7 ± 12.6	1a. 58.4 ± 12.8
		1c. 32/52	1d. 34/5 ± 23.8	1b. 33.2 ± 22.3	1b. 26.4 ± 18.4
		1d. 52/52	2a. 34.3 ± 7.2	1c. 35.7 ± 23.9	1c. 28.2 ± 21.6
		2a.	2b. 19.2 ± 10.1	1d. 34/8 ± 21.2	1d. 31.7 ± 22.6
		Baseline	2c. 21.4 ± 12.0	2a. 35.0 ± 7.4	2a. 35.7 ± 7.3
		2b. 12/52	2d. 18.1 ± 11.2	2b. 23.5 ± 10.6	2b. 15.4 ± 9.2
		2c. 32/52	3a. 63.6 ± 26.3	2c. 23.4 ± 12.2	2c. 17.5 ± 10.8
		2d. 52/52	3b. 59.9 ± 26.6	2d. 21.3 ± 9.8	2d. 16 ± 10.3
		3a.	3c. 59.2 ± 24.4	3a. 69.5 ± 23.7	3a. 65.8 ± 25.7
		Baseline	3d. 62.5 ± 26.0	3b. 82.9 ± 26.2	3b. 82.8 ± 27.0
		3b. 12/52	4a. 1.13 ± 0.49	3c. 78.5 ± 24.8	3c. 80.1 ± 26.6
		3c. 32/52	4b. 1.28 ± 0.52	3d. 79.7 ± 25.9	3d. 81.4 ± 26.3
		3d. 52/52	4c. N/A	4a. 1.00 ± 0.45	4a. 0.99 ± 0.43
		4a.	4d. 1.34 ± 0.52	4b. 1.08 ± 0.49	4b. 1.13 ± 0.48
		Baseline	5a. 9.0 ± 2.6	4c. N/A	4c. N/A
		4b. 12/52	5 b. 11.1 ± 3.0	4d. 1.10 ± 0.44	4d. 1.23 ± 0.44

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Author, Year	Functional Outcome Measure(s)	Results			
		Timepoint	Control Mean ± SD	Intervention Mean ± SD	
Bennell et al., 2017	(Bennell and Hinman, 2011) NRS (0–10) (Hawker et al.) WOMAC Pain (Vitaloni et al.) WOMAC function (Fransen et al., 2015) AQoL	4c. 32/52	5c. N/A	5a. 8.2 ± 3.0	5a. 8.8 ± 2.4
		4d. 52/52	5 d. 11.6 ± 2.8	5b. 9.0 ± 3.3	5b. 10.6 ± 3.0
		5a.	6a. 1.54 ± 0.35	5c. N/A	5c. N/A
		Baseline	6 b. 1.73 ± 0.34	5d. 9.6 ± 3.5	5d. 11.1 ± 2.3
		5b. 12/52	6c. N/A	6a. 1.51 ± 0.30	6a. 1.53 ± 0.20
		5c. 32/52	6d. 1.74 ± 0.37	6b. 1.58 ± 0.33	6b. 1.58 ± 0.33
		5d. 52/52		6c. N/A	6c. N/A
		6a.		6d. 1.63 ± 0.39	6d. 1.78 ± 0.36
		Baseline			
		6b. 12/52			
		6c. 32/52			
		6d. 52/52			
		1a.	1a. 5.8 ± 2.5	1a. 5.6 ± 1.4	
		Baseline	1b. 3.8 ± 2.3	1b. 3.1 ± 2.2	
		1b. 6/12	1c. 3.7 ± 2.2	1c. 3.2 ± 2.4	
		1c. 12/12	1d. 4.1 ± 28.8	1d. 3.6 ± 2.4	
		1d. 18/12	2a. 8.5 ± 2.9	2a. 8.1 ± 2.7	
		2a.	2b. 5.7 ± 3.6	2b. 4.2 ± 3.0	
		Baseline	2c. 5.4 ± 3.4	2c. 4.3 ± 3.3	
		2b. 6/12	2 d. 4.3 ± 3.5	4.4 ± 3.4	
		2c. 12/12	3a. 30.3 ± 10.1	3a. 27.3 ± 11.1	
		2 d. 18/12	3b. 18.2 ± 11.7	3b. 14.7 ± 10.6	
		3a.	3c. 17.4 ± 11.9	3c. 13.3 ± 10.5	
		Baseline	3d. 16.4 ± 11.7	3d. 12.2 ± 10.5	
3b. 6/12	4a. 0.7 ± 0.1	4a. 0.7 ± 0.1			
3c. 12/12	4b. 0.8 ± 0.1	4b. 0.8 ± 0.1			
3d. 18/12	4c. 0.8 ± 0.1	4c. 0.8 ± 0.2			
4a.	4d. 0.8 ± 0.2.	4d. 0.8 ± 0.1			
Baseline					
4b. 6/12					
4c. 12/12					
4d. 18/12					
Bennell et al., 2020	(Bennell and Hinman, 2011) NRS (0–10) (Hawker et al.) KOOS pain (0–100) (Vitaloni et al.) KOOS function (0–100) (Fransen et al., 2015) KOOS QoL (0–100) (Stewart) AQoL (–0.04 – 1.0)	1a.	1a. 3.8 ± 2.4	1a. 3.5 ± 2.1	
		Baseline	1b. 4.0 ± 2.3	1b. 4.1 ± 2.2	
		1b. 24/52	2a. 63.2 ± 19.8	2a. 64.3 ± 14.9	
		2a.	2b. 64.4 ± 20.1	2b. 64.9 ± 17.3	
		Baseline	3a. 70.6 ± 20.7	3a. 72.2 ± 15.6	
		2b. 24/52	3b. 70.0 ± 21.1	3b. 72.4 ± 17.6	
		3a.	4a. 47.9 ± 21.7	4a. 44.4 ± 19.9	
		Baseline	4b. 47.8 ± 23.0	4b. 46.1 ± 22.0	
		3b. 24/52	5a. 0.81 ± 0.12	5a. 0.76 ± 0.18	
		4a.	5b. 0.78 ± 0.15	5b. 0.77 ± 0.15	
		Baseline			
		4b. 24/52			
		5a.			
		Baseline			
		5b. 24/52			
Bokaeian et al., 2021	1) VAS (0–100) (Hawker et al.) WOMAC pain (Vitaloni et al.) 2MWT (distance - m) (Fransen et al., 2015) 2MWT (gait speed - m/s)	1a.	1a. 69.3 ± 13.7	1a. 78.1 ± 18.4	
		Baseline	1b. 41.2 ± 29.9	1b. 35.3 ± 8.7	
		1b. 1/12	1c. 44.4 ± 26.6	1c. 39.8 ± 36	
		1c. 2/12	2a. 17.4 ± 3.6	2a. 16.2 ± 4.1	
		2a.	2b. 7.9 ± 4.6	2b. 6.9 ± 6	
		Baseline	2c. 10.5 ± 3.9	2c. 6.4 ± 4.7	
		2b. 1/12	3a. 120.4 ± 21.9	3a. 12 ± 20.9	
		2c. 2/12	3b. 138.1 ± 14.5	3b. 144.8 ± 26.1	
		3a.	3c. 136 ± 16.7	3c. 136.2 ± 25.1	
		Baseline	4a. 0.84 ± 0.12	4a. 0.88 ± 0.1	
		3b. 1/12	4b. 0.8 ± 0.2	4b. 0.9 ± 0.09	
		3c. 2/12	4c. 0.86 ± 0.09	4c. 0.87 ± 0.1	
		4a.			
		Baseline			
		4b. 1/12			
4c. 2/12					
Chen, 2019	(Bennell and Hinman, 2011) NRS (0–10) (Hawker et al.) WOMAC (Vitaloni et al.) 5 × STS (s) (Fransen et al., 2015) TUG (s)	1a.	1a. 22.64 ± 19.34	1a. 21.69 ± 19.97	
		Baseline	1b. 23/47 ± 17.11	1b. 16.85 ± 15.09	
		1b. 12/52	1c. 22.71 ± 19.57	1c. 16.18 ± 15.94	
		1c. 24/52	2a. 24.13 ± 26.73	2a. 24.16 ± 26.10	
		2a.	2b. 22.92 ± 22.0	2b. 19.10 ± 20.91	
		Baseline	2c. 19.62 ± 19.88	2c. 10.41 ± 12.52	
		2b. 12/52	3a. 12.12 ± 4.41	3a. 11.98 ± 5.34	
		2c. 24/52	3b. 12.11 ± 3.81	3b. 11.19 ± 4.07	
		3a.	3c. 11.34 ± 3.66	3c. 9.61 ± 2.43	
		Baseline	4a. 9.12 ± 2.02	4a. 8.91 ± 3.03	

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Author, Year	Functional Outcome Measure(s)	Results			
		Timepoint	Control Mean ± SD	Intervention Mean ± SD	
		3b. 12/52	4b. 8.92 ± 1.88	4b. 8.45 ± 2.0	
		3c. 24/52	4c. 8.56 ± 1.7	4c. 7.46 ± 1.26	
		4a. Baseline			
		4b. 12/52			
		4c. 24/52			
Farr et al., 2010		(Bennell and Hinman, 2011) and (Hawker et al.) WOMAC pain (Hawker et al.) Moderate physical activity level - 3-6 METs (Vitaloni et al.) Vigorous physical activity level - >6 METs	1a. Baseline 1b. 3/12 1c. 9/12 2a. Baseline 2b. 3/12 2c. 9/12 3a. Baseline 3b. 3/12 3c. 9/12	1a. 84.3 ± 70.1 1b. 47.6 ± 50.9 1c. 48.6 ± 61.3 2a. 24.6 ± 17.8 2b. 27.9 ± 19.4 2c. 26.1 ± 17.7 3a. 0.8 ± 2.6 3b. 2.1 ± 4.9 3c. 1.6 ± 4.2	1a. 81.9 ± 67.3 1b. 67.1 ± 68.8 1c. 56.2 ± 75.3 2a. 27.9 ± 18.3 2b. 32.1 ± 17.1 2c. 30.1 ± 15.0 3a. 1 ± 2 3b. 1.6 ± 2.5 3c. 1.9 ± 3.7
Focht et al., 2014	(Bennell and Hinman, 2011) Function - 400 m walk time (s) (Hawker et al.) Physical activity level	1a. Baseline 1b. 3/12 1c. 12/12 2a. Baseline 2b. 3/12 2c. 12/12	1a. 385.8 ± 120.4 1b. 382.3 ± 112.2 1c. 419.4 ± 196.9 2a. 352.5 ± 299.5 2b. 299.1 ± 179.2 2c. 278.3 ± 179.2	1a. 357.6 ± 98.5 1b. 347 ± 95.6 1c. 351.3 ± 95.5 2a. 351 ± 196.8 2b. 410.3 ± 246.4 2c. 404.5 ± 251.8	
Keefe et al., 2004	(Bennell and Hinman, 2011) Coping strategies questionnaire (Hawker et al.) VO2K (Vitaloni et al.) The Arthritis Self-Efficacy Scale	1a. Baseline 1b. 12/52 2a. Baseline 2b. 12/52 3a. Baseline 3b. 12/52	1a. 49.35 ± 26.61 1b. 47.44 ± 20.29 2a. 21.37 ± 5.74 2b. 24.35 ± 5.97 3a. 215.42 ± 36.95 3b. 220.46 ± 44.66	Intervention A (PCST) 1a. 69.36 ± 26.33 1b. 78.18 ± 23.96 2a. 20.36 ± 6.77 2b. 20.40 ± 7.21 3a. 201.93 ± 45.69 3b. 234.13 ± 37.43	Intervention B (PCST + Ex) 1a. 55.19 ± 32.27 1b. 73.76 ± 25.78 2a. 20.42 ± 5.48 2b. 24.03 ± 5.88 3a. 196.68 ± 41.68 3b. 238.71 ± 31.61
Messier et al., 2004	(Bennell and Hinman, 2011) WOMAC Pain - change in score, 0-20 (Hawker et al.) 6MWT (m) (Vitaloni et al.) Stair climb	1a. Baseline 1b. 6/12 1c. 18/12 2a. Baseline 2b. 6/12 2c. 18/12 3a. Baseline 3b. 6/12 3c. 18/12	1a. 6.64 ± 0.39 1b. 6.22 ± 0.45 1c. 6.24 ± 0.47 2a. 424.15 ± 11.42 2b. 465.04 ± 12.13 2c. 472.73 ± 13.12 3a. 10.52 ± 0.66 3b. 8.87 ± 0.73 3c. 8.89 ± 0.78	Intervention A (D) 1a. 6.58 ± 0.40 1b. 5.10 ± 0.43 1c. 5.51 ± 0.45 2a. 425.98 ± 10.89 2b. 433.68 ± 11.94 2c. 435.63 ± 12.88 3a. 9.74 ± 0.65 3b. 9.88 ± 0.70 3c. 8.43 ± 0.78	Intervention B (D + Ex) 1a. 7.27 ± 0.41 1b. 5.47 ± 0.47 1c. 5.07 ± 0.47 2a. 416.65 ± 11.34 2b. 482.37 ± 12.65 2c. 477.76 ± 13.12 3a. 10.99 ± 0.67 3b. 8.83 ± 0.78 3c. 8.45 ± 0.81
Rejeski, 2010	1. SF-36 mental health 2. SF-36 physical health 3. SF-36 satisfaction w/function 4. SF-36 satisfaction w/appearance	1a. Baseline 1b. 6/12 1c. 18/12 2a. Baseline 2b. 6/12 2c. 18/12 3a. Baseline 3b. 6/12 3c. 18/12	1a. 54.28 ± 1.0 1b. 52.85 ± 1.26 1c. 54.06 ± 0.81 2a. 34.50 ± 1.14 2b. 37.14 ± 1.25 2c. 37.61 ± 0.85 3a. -1.09 ± 0.18 3b. -0.13 ± 0.20 3c. -0.09 ± 0.16 4a. -1.31 ± 0.13 4b. -0.93 ± 0.19 4c. -0.96 ± 0.16	Intervention A (D) 1a. 52.69 ± 1.04 1b. 53.89 ± 0.97 1c. 54.39 ± 0.78 2a. 35.17 ± 1.05 2b. 38.20 ± 1.13 2c. 38.15 ± 0.81 3a. -0.99 ± 0.19 3c. 0.19	Intervention B (D + Ex) 1a. 52.85 ± 1.31 1b. 53.31 ± 0.99 1c. 53.84 ± 0.82 2a. 35.39 ± 1.28 2b. 40.57 ± 1.33 2c. 40.31 ± 0.86 3a. -1.04 ± 0.17 3b. -.39 ± 0.22 3c. 0.38 ± 0.17 4a. -1.78 ± 0.19

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Author, Year	Functional Outcome Measure(s)	Results		
		Timepoint	Control Mean ± SD	Intervention Mean ± SD
		4a. Baseline		3b. -0.24 ± 0.18
		4b. 6/12		4b. -0.44 ± 0.21
		4c. 18/12		4c. -0.46 ± 0.16
				3c. -0.30 ± 0.16
				4a. -1.94 ± 0.15
				4b. -0.81 ± 0.18
				4c. -0.70 ± 0.15
Veenhof et al., 2006	(Bennell and Hinman, 2011) VAS: 0–10 (change to baseline) (Hawker et al.) WOMAC Pain: 0–20 (change to baseline) (Vitaloni et al.) WOMAC Function: 0–68 (change to baseline) (Fransen et al., 2015) 5 m walk test: S (change to baseline) (Stewart) SF-36: 0–100 (change to baseline)	1a. Baseline	1a. 3.7 ± 2.5	1a. 4.3 ± 2.8
		1b. 13/52	1b. -0.47 (-1, 0.1)	1b. -0.61 (-1.2, 0.005)
		1c. 39/52	1c. 0.62 (0, 1.2)	1c. -0.15 (-0.8, -0.5)
		1d. 65/52	1d. -0.58 (-1.1, -0.3)	1d. -1.01 (-1.7, -0.3)
		2a. Baseline	2a. 8.7 ± 3.1	2a. 9.1 ± 3.3
		2b. 13/52	2b. -2.20 (-2.9, -1.5)	2b. -2.35 (-3, -1.7)
		2c. 39/52	2c. -1 (-1.8, -0.2)	2c. -2.30 (-3.3, -1.3)
		2d. 65/52	2d. -3.2 (-3.9, -2.5)	2d. -3.90 (-4.7, -3.1)
		3a. Baseline	3a. 29.1 ± 9.9	3a. 28.7 ± 12.5
		3b. 13/52	3b. -5.21 (-6.9, -3.5)	3b. -5.98 (8.0, -4.0]
		3c. 39/52	3c. -5.22 (-7.4, -3.0)	3c. -6.94 (-9.6, -4.3)
		3d. 65/52	3d. 7.29 (9.3, 5.2)	3d. 7.35 (10.4, 4.3)
		4a. Baseline	4a. 4.8 ± 1.5	4a. 4.8 ± 1.2
		4b. 13/52	4b. -0.19 (-0.4, 0)	4b. -0.41 (-0.6, -0.2)
		4c. 39/52	4c. No data	4c. No data
		4d. 65/52	4d. -0.13 (-0.3, -0.04)	4d. -0.44 (-0.7, -0.2)
		5a. Baseline	5a. 45.2 ± 41.7	5a. 4 ± 4.7
		5b. 13/52	5b. 15.2 (5.1, 25.2)	5b. 14.1 (4.9, 23.3)
		5c. 39/52	5c. 9.2 (-1.4, 19.9)	5c. 12.1 (1.6, 22.5)
		5d. 65/52	5d. 17.8 (6, 29.5)	5d. 8 (-3.7, 19.7)
Wang et al., 2016 ⁸	1. WOMAC pain (0–500, mm) 2. WOMAC physical function (0–1700, mm) 3. WOMAC stiffness (0–200, mm) 4. Patient Global Assessment score (0–10 cm) 5. Beck Depression inventory-II (0–63) 6. SF-36 physical (0–100) 7. SF-36 mental (0–100) 8. Arthritis self-efficacy scale (Bennell and Hinman, 2011; Hawker et al.; Vitaloni et al.; Fransen et al., 2015; Stewart; Cross et al.; Woolf and Pfleger; Ackerman et al. Mahendira et al.; Chen et al., 1941) 9.6 min walk test (m) 10.20 m walk test (s) 11. NSAID consumption	1b. 12/52	1b. -143.0	1b. -167.2 (-190.4 to -144.9)
		1c. 24/52	(-167.4 to -118.6)	1c. -158.6 (-182.9 to -134.3)
		1d. 1 year	-124.3	1d. -138.8 (-166.7 to -110.8)
		2b. 12/52	(-150.0 to -98.5)	2b. -608.3 (-695.3 to -521.4)
		2c. 24/52	1d. -121.0	2c. -586.8 (-669.5 to -504.1)
		2d. 1 year	(-150.0 to -91.9)	2d. -532.3 (-625.9 to -438.7)
		3b. 12/52	3b. -494.2	3b. -494.2 (-585.3 to -403.2)
		3c. 24/52	(-585.3 to -403.2)	3c. -455.7 (-543.1 to -368.4)
		3d. 1 year	2c. -455.7	3d. -444.0 (-541.3 to -346.7)
		4b. 12/52	(-543.1 to -368.4)	4b. -2.96 (-3.46 to -2.45)
		4c. 24/52	2d. -444.0	4c. -2.40 (-2.93 to -1.88)
		4d. 1 year	(-541.3 to -346.7)	4d. -1.84 (-2.48 to -1.21)
		5b. 12/52	3b. -494.2	5b. -2.2 (-3.7 to -0.9)
		5c. 24/52	(-585.3 to -403.2)	5c. -1.7 (-3.1 to -0.4)
		5d. 1 year	3c. -455.7	5d. -1.1 (-2.7 to 0.5)
		6b. 12/52	(-543.1 to -368.4)	6b. 6.3 (4.6-7.9)
		6c. 24/52	3d. -444.0	6c. 7.1 (5.1-9.0)
		6d. 1 year	(-541.3 to -346.7)	6d. 6.3 (4.4-8.3)
		7b. 12/52	4b. -2.24 (-2.78 to -1.71)	7b. 1.6 (-0.1 to 3.2)
		7c. 24/52	7c. -1.73 (-2.29 to -1.17)	7c. 0.4 (-1.5 to 2.2)
		7d. 1 year	4c. -1.73 (-2.29 to -1.17)	7d. -0.1 (-1.9 to 1.8)
		8a. Baseline	4d. -1.31 (-1.96 to -0.66)	8b. 1.3 (0.8-1.8)
		8b. 12/52	5b. 0.5 (-1.0 to 2.0)	8c. 0.9 (0.4-1.4)
		8c. 24/52	5c. 0.2 (-1.3 to 1.7)	8d. 1.0 (0.5-1.5)
		8d. 1 year	5d. -0.003 (-1.6 to 1.6)	9b. 28.6 (17.9-39.2)
		9b. 12/52	6b. 3.1 (1.4-4.8)	9c. 28.9 (16.6-41.2)
		9c. 24/52	6c. 3.4 (1.4-5.5)	9d. 27.1 (12.2-42.0)
		9d. 1 year	6d. 4.3 (2.3-6.4)	10b. -1.6 (-2.4 to -0.8)
		10b. 12/52	7b. -0.03 (-1.7 to 1.7)	10c. -2.4 (-3.4 to -1.3)
		10c. 24/52	7c. -0.7 (-2.7 to 1.4)	10d. -2.4 (-3.5 to -1.4)
		10d. 1 year		11b. 0.39 (0.18-0.87)
		11b. 12/52		11c. 0.17 (0.07-0.40)
		52		11d. 0.39 (0.17-0.92)

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Author, Year	Functional Outcome Measure(s)	Results			
		Timepoint	Control Mean ± SD	Intervention Mean ± SD	
Wang et al., 2020		11c. 24/52	7d. -1.5 (-3.4 to 0.4)		
		11d. 1 year	8b. 0.8 (0.3-1.4) 8c. 0.9 (0.4-1.4) 8d. 0.7 (0.2-1.2) 9b. 26.1 (14.9-37.4) 9c. 24.5 (11.5-37.5) 9d. 22.8 (7.0-38.6) 10b. -1.1 (-2.0 to -0.2) 10c. -1.2 (-2.2 to -0.1) 10d. -1.0 (-2.1 to 0.2) 11b. 0.54 (0.24-1.21) 11c. 0.61 (0.26-1.42) 11d. 0.75 (0.32-1.77)		
		1. WOMAC pain	1a. Baseline 1b. 24/52 1c. 48/52	1a. 24.42 ± 19.65 1b. 23.47 ± 17.11	1a. 24.37 ± 20.31 1b. 16.18 ± 15.94 1c. 13.62 ± 11.28
		2. WOMAC stiffness	2a. Baseline 2b. 24/52 2c. 48/52	2a. 17.11 2b. 19.64 ± 16.83	2a. 24.03 ± 24.73 2b. 10.53 ± 12.49 2c. 9.77 ± 14.19
		3. FTSSST	3a. Baseline	2a. 25.00 ±	3a. 12.03 ± 5.09
		4. TUG	3b. 24/52 3c. 48/52 4a. Baseline 4b. 24/52 4c. 48/52	25.37 2b. 19.62 ± 19.88 2c. 17.57 ± 21.36	3b. 9.61 ± 2.43 3c. 10.29 ± 3.70 4a. 2.95 ± 0.29 4b. 1.26 ± 0.13 4c. 1.11 ± 0.12
				3a. 12.27 ± 4.29 3b. 11.34 ± 3.66 3c. 11.06 ± 2.79 4a. 2.03 ± 0.22 4b. 1.60 ± 0.19 4c. 1.22 ± 0.15	

Ex Exercise, VAS Visual Analogue Scale, WOMAC Western Ontario and McMaster Universities Osteoarthritis, STS Sit-to-stand, PCST Pain Coping Strategy Training, NRS Numerical rating scale, AQoL Assessment of Quality of Life, KOOS Knee Injury and Osteoarthritis Outcome Score, 2MWT 2-m Walk Test, STS Sit-to-stand, TUG Timed up-and-go, D Diet, 6MWT 6-min Walk Test, QoL Quality of life, NSAID Non-steroidal anti-inflammatory drug, BGA Behaviour Graded Activity, FTSSST Five-time Sit-to-Stand.

**Jenkinson et al. (2009) and Mihalko et al. (2018) were not included in this table as numerical results data was no published in full.

§ Wang et al. (2016) did not report baseline values in numerical form.

Appendix E. GRADE rating for certainty of evidence

Meta-analysis outcome	Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Rating
Pain intensity SMD -0.61; 95% CI. -1.12 to -0.10; I ² = 95%	0	-1 [§]	-1*	-1 [†]	0	-3
Knee joint stiffness at 6 months – WOMAC stiffness) MD -0.69; 95% CI. -1.21 to -0.17; I ² = 0%	0	0	0	0	0	0
Quality of Life at 6 months (AQoL) MD -0.10; 95% CI. -0.24 to 0.04; I ² = 0%	0	0	-1*	0	0	-1
Physical function at 6 months (TUG) MD -1.26 s; 95% CI. -1.34 to -1.17; I ² = 0%	0	0	0	-1 [†]	0	-1

GRADE Grade of Recommendation, Assessment Development and Evaluation; 0 Not downgraded.

*Downgraded 1 place because of unexplained indirectness.

† Downgraded 1 place because of wide CI.

§ Downgraded 1 place for evidence of unexplained inconsistency (I² = >50%).

‡ Funnell plots not completed due to <10 studies included in meta-analysis.

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