Common exercise prescription for management of weight and osteoarthritis: A Systematic Review

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Abstract

Background: Obesity and osteoarthritis are two debilitating conditions that are increasing in prevalence. Obese populations are at an increased risk for developing osteoarthritis in later life. Exercise has been shown to be successful in improving both weight status and musculoskeletal pain, yet it remains unclear if there is an exercise intervention that results in improved weight status while preventing the development of osteoarthritis.

Objective: The purpose of this systematic review is to investigate the existence of a natural overlap in exercise prescription for obese and osteoarthritic populations and recommend an evidence-based exercise intervention for the management of weight and prevention of musculoskeletal pain.

Methods: A structured electronic review was conducted using the following electronic databases: MEDLINE, PubMed, and SPORTDiscus. Two searches were performed using the search strings "obes*" AND "exercise" AND "interven*" AND "musculoskeletal pain OR knee pain OR hip pain" and "osteoarth*" AND "exercise" AND "interven*" AND "musculoskeletal pain OR knee pain OR hip pain". Studies were then reviewed using inclusion/exclusion criteria (exclusion criteria: menopausal, cancer, review, obesity related co-morbidities, animal studies; inclusion criteria: studies had to be randomised controlled trials, participants aged 18-50, include non-exercise control, and outcomes must include physical function or musculoskeletal pain). Included studies were ranked by change in measured outcome variables (descending order); a summary of recommended exercise prescription was based on common prescription used in the interventions with greatest change. A Downs and Black checklist was completed for all studies included in this review to assess methodological quality.

Results: Twenty-one studies met inclusion criteria and were included in this review (obesity n = 11; OA n = 7; obesity & OA n= 3). Exercise significantly improved weight status and/or musculoskeletal pain. Similarities in exercise intensity (40-80% VO_{2max}), frequency (3 times per week), duration (30-60 minutes), and exercise mode (treadmill, cross-trainer, stationary bike, aquatic exercise) were observed between studies.

Conclusion: Substantial overlap in exercise prescription for obese and OA populations exist. These findings suggest that moderate intensity exercise for 30-60 minutes, 3 times per weeks can achieve effective improvements in weight and musculoskeletal pain. Exercise and weight loss are effective treatments for obesity and musculoskeletal symptoms and should be recommended to all at-risk individuals.

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1. Introduction

Chronic health conditions such as obesity and osteoarthritis (OA) are quickly becoming major health and economic burdens as the incidence of both conditions increase. The two conditions have been closely linked, and obesity is a widely accepted risk factor for the development of OA (1). In fact, over a quarter of all US adults diagnosed with OA are also classified as having obesity (2). Osteoarthritis prevalence has doubled since the mid twentieth century and in the United States alone, 19% of adults over 45 years of age are thought to have knee OA (3). With the aging population increasing annually, it can be expected that the incidence of both obesity and OA will continue to increase. Musculoskeletal pain is associated with both conditions and is a major contributor to disability in these populations (3-6), with microscopic (individual) and macroscopic (economic) impact (7). While the cost of obesity has been estimated at $2trillion USD, the financial impact of OA is more complicated as the cost is often associated with general musculoskeletal complaints and treatments. However, it has been estimated that the direct all cause cost of OA may be as high as US $136.8 billion (8, 9).

Exercise is a common intervention that is prescribed for both obesity and OA. Current guidelines for both clinical populations exist (5, 10, 11), and exercise has been shown to have a positive influence on obesity and OA in regard to improved function, particularly within activities of daily living, and a reduction in musculoskeletal pain (5, 10, 11). For example, exercise interventions such as resistance training have been shown to improve functional capacity, improve joint range of motion, and reduce pain in both obese and OA populations (12, 13). Aerobic training (such as walking and cycling) have also been shown to be effective for both obesity and OA in improving exercise tolerance, weight loss, and pain reduction (14, 15). However, identifying exercise modalities to prevent the onset of OA are currently lacking. To this point, investigation of exercise interventions for both conditions could provide insight for the development of an optimal exercise plan to assist in treating obesity while also preventing the onset of OA. This natural overlap in exercise prescription for both conditions could then be further investigated to provide an exercise intervention that maximises beneficial results while also minimising the risk of joint injury or OA aggravation amongst obese.

The purpose of this systematic review is to highlight similarities in exercise interventions for both obese and osteoarthritic populations and to recommend an evidence-based exercise program that would benefit individuals with obesity and OA. Specifically, the systematic review investigated the natural overlap in effective exercise interventions for obesity and OA, thus exploring best practice for optimising health outcomes and reducing the long-term risk of joint injury for both populations.

2. Methods

2.1 Identification of Studies

Figure 1 presents the protocol used to systematically assess the available literature. A structured electronic literature search was conducted using the following online databases: MEDLINE, PubMed, and SPORTDiscus. Two searches were performed. The first focused on populations with obesity and used the following search strings: "obes*" AND "exercise" AND "interven*" AND "musculoskeletal pain OR knee pain OR hip pain". The second search focused on osteoarthritic populations and used the following search strings: "osteoarth*" AND "exercise" AND "interven*" AND "musculoskeletal pain OR knee pain OR hip pain". The total number of articles resulting from the obesity-focused and osteoarthritis-focus search were 15588 and 2462, respectively. Titles were then exported to separate EndNote files for processing. After duplicates were removed, the number of articles relating to obesity (N=8366) and osteoarthritis (N=1275) was reduced based on predefined inclusion and exclusion criteria.

2.2 Inclusion and Exclusion Criteria.

Only randomised controlled trials published in peer-reviewed journals were considered for assessment. Reviews, conference proceedings, abstracts, and theses were not included. Studies were assessed by screening titles and abstracts. If suitability could not be determined during this process, full-text articles were accessed and compared against inclusion criteria. Once all titles had been reviewed, a full-text version was accessed for the remaining articles. The methods and results sections of each article were assessed to ensure the articles were randomised controlled trials and met the inclusion/ exclusion criteria outlined below. Where the exercise intervention was unclear (15), the corresponding author was contacted to seek further detail.

One author (DB) independently assessed eligibility for inclusion using the criteria below. Where agreement could not be reached, two other authors (SS and LA) were consulted to determine eligibility for inclusion.

1. The following key words were used to exclude studies from EndNote:
    a. Menopausal, polycystic, cancer, review (including systematic review), diabetes, stroke, canine, feline, animal, mice, rodent, rat, non-alcoholic (fatty liver disease), any other obesity co-morbidity.
2. Although studies could include older or younger participants, at least part of the study cohort must include participants between 18-50 years old. The criterion was not based on mean age.

3. Research methodology had to identify as a randomized control trial.
4. Studies must have at least one non-exercise control group and one exercise only group.
5. All studies must include either physical function or musculoskeletal pain as an assessed outcome.

There were 11 articles related to obesity, and 7 articles related to OA, that met the criteria. Additionally, there were 3 studies that included participants with obesity and osteoarthritis.

2.3 Criteria for *Assessment* of Methodological Quality

Authors (SM, JD, MP, CN, HV) assessed the methodological quality of each included study using a previously published and validated checklist (16) . The check list, developed by Downs and Black (16), included 26 items distributed between the following five subscales:

1. Reporting (9 items)
2. External validity (3 items)
3. Bias (7 items)
4. Confounding (6 items)
5. Power (1 item)

Briefly, the Reporting sub-section includes items to assess that the information provided in each paper was sufficient to allow the reader to assess the results from the article without bias. The external validity sub-section addresses whether findings from each article can be generalized to the population of the participants involved in the study. The bias sub-section focuses on whether bias in the measurement of the outcome for each intervention exists in each article. The confounding subsection examined whether there is bias in the selection of study participants. The power sub-section determines if the negative findings from a study could be due to chance. Twenty four of the 26 items were scored as meeting (1) or not meeting (0) the item criteria. One item in the power section required a scalar score between

0-5, based on the minimum number of participants in each group. Each article was scored by two independent reviewers; the maximum score for an article was 31. Downs and Black scores were classified as being excellent (31-29), good (28-23), fair (22-18), and poor (≤17), based on previous research (7). If there was a lack of consensus between the reviewers concerning the score classification (i.e. excellent, good, fair poor) then a third reviewer acted as arbitrator to reach agreement.

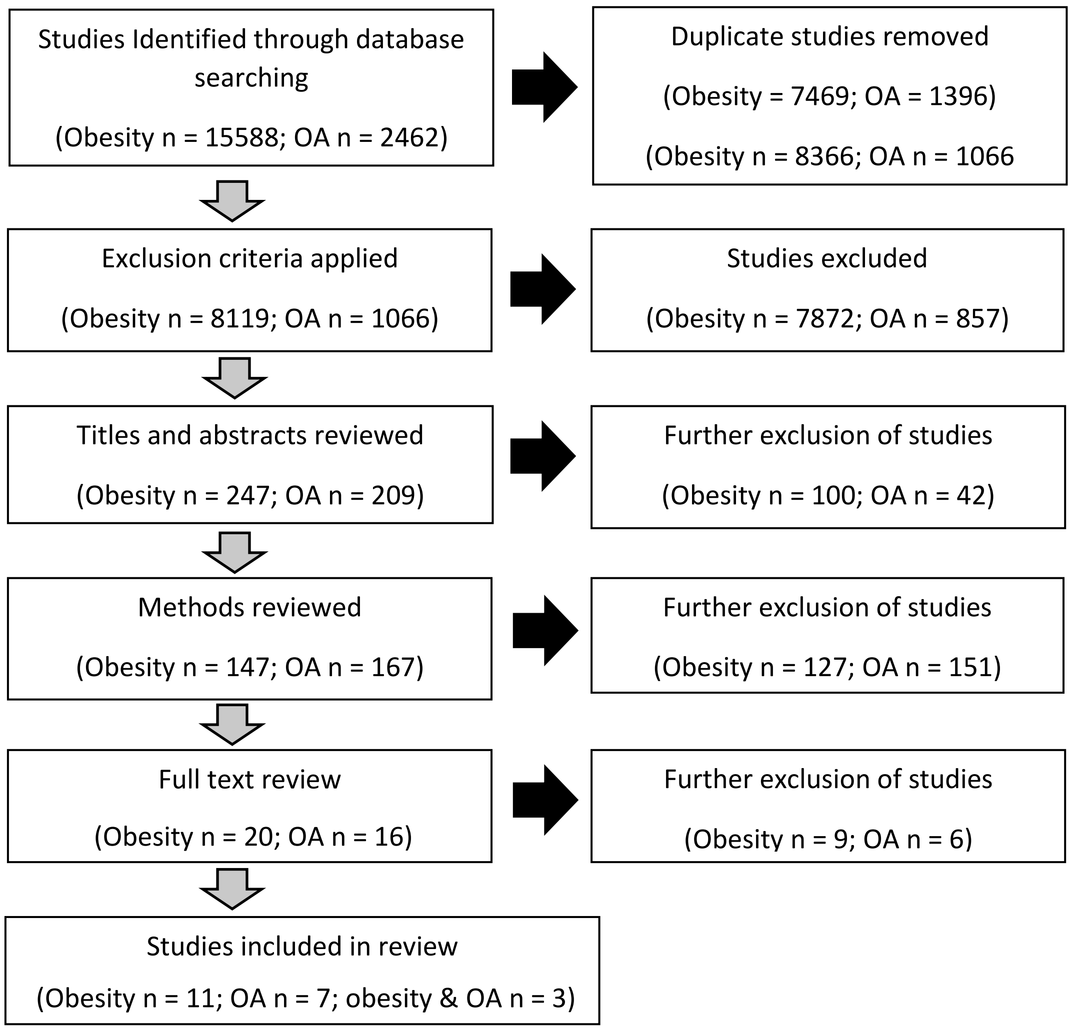

Fig 1. Study progression during inclusion/ exclusion

3. Results

3.1 Participant Characteristics

There were a total of 2985 participants for the included studies (637 men and 1502 women, where reported; average age = 51, average BMI = 32.2, where reported; average BF% = 37.2, where reported). The majority of obesity-related studies reported body mass index (BMI) and body fat percentage as being specifically obese (BMI>30 kg/m^2; BF%>30%); only two study studies (12, 17) had a mean BMI associated with overweight (BMI=29.33 kg/m and 27kg/m^2 respectively). OA was classified either by radiographic evidence or according to the clinical criteria of the American College of Rheumatology for the majority of OA-related studies; two studies did not identify the protocol used to classify OA (18, 19). Inclusion and/or exclusion criteria were stated in all but three studies (20-22).

3.2 Study Interventions

Only randomized controlled trial (RCT) research designs were included in the final studies. Examples of control groups included advice leaflet only, no treatment, usual care, and weekly telephone surveys. Exercise interventions for both populations varied in duration, length, mode, and intensity (Table 1).

Intervention duration in the selected studies ranged from 3 weeks (23) to two years (19, 24); an intervention duration of 12 weeks was most common (13, 21, 25-28). Exercise session length varied from 20-90 minutes for the selected studies. The frequency of exercise also varied from two times per week to daily; however, three times per week was the most common frequency (13, 14, 20, 22, 23, 25-27, 29-31).

The mode of exercise also varied between studies. Both aerobic training and resistance training were commonly used as the exercise mode for selected studies. Aerobic exercise included the use of weight bearing (treadmill, walking), non-weight bearing (cycling, aquatic exercise, rowing machine), and partial weight bearing (cross-trainer) modalities. Resistance training focussed heavily on strengthening the muscles around the hip as well as the quadriceps muscles. Resistance training included the use of resistance bands, bodyweight exercises, water resistance, and resistance machines.

Exercise intensity ranged from low intensity such as normal walking through to 90% of maximal heart rate for some interval-based training. Most studies required a moderate intensity of approximately 40-70% of maximal heart rate during aerobic training and 40-60% 1-repetition maximum during resistance-based training.

3.3 Effect on Outcome Measures

Where body composition was measured in a study, 8 studies reported statistically significant weight loss (range: 1-6.72 kg) (14, 21, 25, 26, 30) and reductions in BMI (range: 0.63-2. 35 kg/m^2) (13, 14, 25, 26, 31); one study also reported a statistically significant reduction in body fat percentage (0.2%) (28); however, these changes may be too small to be considered of clinical importance. High intensity exercise appeared to result in more weight loss when compared to moderate or low intensity exercise. In addition to weight loss, exercise also improved gas exchange threshold (29), fat oxidation (29), muscle cross sectional area (23), muscle torque (20), walking distance (32), stride length (32), walking speeds (32), and peak O_2 uptake (21, 33).

Improvements in musculoskeletal pain and physical function were measured using well validated and accepted instruments : Lequesne Index (12, 20, 31), WOMAC (write out) (17-19, 27, 31), 36-Item Short Form Health Survey (SF-36) (12, 18, 27), Visual Analog Scale (VAS) (20, 30), and Hip disability and Osteoarthritis Outcome Score (HOOS) (15). All studies showed significant improvements in musculoskeletal pain and physical function when compared to a control group.

3.4 Assessment of Methodological Quality

All included studies were assessed by two reviewers to identify level of research quality. The overall scores of each reviewer were classified as excellent, good, fair, or poor. If the classifications differed between reviewers, the study was sent to a third reviewer for arbitration. Of the 21 included studies, eleven were sent to KA for arbitration. Table 3 presents the average overall score and resulting classification for each study. There were seven studies classified as poor (13, 20-23, 29, 33), eleven studies classified as fair (12, 14, 18, 24-28, 30-32), and three studies classified as good (15, 17, 19). The lowest score was 12 (20) (poor) and highest was 28 (17) (Good).

Table 1. Description of included studies with obese cohort (N=13)

Study	Participants	Exercise Prescription	Outcome/ Results
Alves, Gale, Mutrie, Correia and Batty (14)	N = 156 Mean age = 38 Mean BMI = 30	• Duration = 6 months • Session length = 50 minutes (3 x weekly) • Exercise Mode = Walking (aerobic) • Intensity = 40-60% HRR	• Significant reduction in weight • Significant reduction in BMI
Arad, DiMenna, Thomas, Tamis-Holland, Weil, Geliebter and Albu (29)	N = 28 Mean BMI = 32.2 Mean BF % = 44.95	• Duration = 14 weeks (3 x weekly) • Exercise mode = cycling (HIT) • Intensity = 4 work intervals (30-60s) at 75-90% HRR. Recovery intervals between work intervals were 180-210s at 50% HRR. Progressive overload until work rest ratio 60s:180s at intensity of 90% HRR for work intervals	• Increase in exercise tolerance • Increase in gas exchange threshold, and fat oxidation at a same absolute maximal workload when compared to control.
Bhutani, Klempel, Kroeger, Trepanowski and Varady (25)	N = 83 Mean Age = 44.5 Mean BMI = 35	• Duration = 12 weeks • Session length = 25 minutes (3 x weekly) • Exercise mode = Stationary bikes and elliptical machines (aerobic) • Intensity = 60% of HRmax. Increase intensity incrementally at weeks 4, 7, and 10 by 5 minutes and 5% HRmax.	• Reduced body weight • Reduced BMI • Reduced fat mass • Reduced waist circumference
Blue, Smith-Ryan, Trexler and Hirsch (23)	N = 44 Mean Age = 35 Mean BMI = 31.4 Mean BF % = 32.7	• Duration = 3 weeks (3 x weekly) • Exercise mode = cycling • Intensity = 10 reps of 1 min bouts at 90% peak power output; 1 min rest between work sets	• Increased muscle CSA significantly.
Chiu, Ko, Wu, Yeh, Kan, Lee, Hsieh, Tseng and Ho (26)	N = 48 Mean Age = 20 Mean BMI = 30 Mean BF % = 36	• Duration = 12 weeks • Session length = 60 minutes (3 x weekly) • Exercise mode = treadmill (aerobic) • Intensity = 40-80% HRR for weeks (increased gradually over 12 weeks)	• Reduction in body weight • Reduced waist circumference, waist-to-hip ratio, and waist-to-height ratio • Reduced BMI • Reduced BF%

Christensen, Henriksen, Leeds, Gudbergsen, Christensen, Sorensen, Bartels, Riecke, Aaboe, Frederiksen, Boesen, Lohmander, Astrup and Bliddal (30)	N = 192 Age = ≥50 Mean BMI = 37.33	• Duration = 52 weeks • Session Length = 45 minutes (3 x weekly) • Exercise mode = Circuit training (includes weight bearing resistance training)	• Reduces pain • Maintenance of weight loss
de Rooij, van der Leeden, Cheung, van der Esch, Hakkinen, Haverkamp, Roorda, Twisk, Vollebregt, Lems and Dekker (17)	N = 126 Age = 45-80 Mean BMI = 35.5	• Duration = 20 weeks • Session length = 30-60 mins (2 x weekly) • Exercise mode = Cycling, rowing, cross trainer, treadmill, rowing (Aerobic) + Resistance • Intensity (Aerobic) = 50-80% VO_2max for moderate intensity (start at 40-50% and raise to 80%). • Intensity (Resistance) = Endurance muscle training = 40-60% 1RM, 2-4 sets, 15-20 reps, 2-3-minute rest between sets. Strength/ power = 60-80% 1RM, 2-4 sets, 8-12 reps, 2-3-minute rest between	• Reduction in WOMAC score • Improved 6-minute walk test • Improved physical functioning
Domene, Moir, Pummell, Knox and Easton (33)	N = 20 Mean Age = 34 Mean BMI = 27 Mean BF % = 31.3	• Duration = 8 Weeks • Session length = 1 hour (12 x classes) • Exercise mode = Aerobic • Intensity = Vigorous	• Increase maximal O_2 uptake • Reduced Body fat % • Improved HRQoL aspects of SF-36
Herring, Wagstaff and Scott (13)	N = 27 Age = 24-68 Mean BMI = 44.45	• Duration = 12 weeks • Session length = 45-60 minutes (3 x weekly) • Exercise mode = Aerobic + Resistance • Intensity (aerobic) = 50-70% HRR • Intensity (strength) = 60% 1RM; 30-60s rest between sets	• Improved shuttle walk test distance • Reduced skin-fold (biceps, triceps, calf) • Improved self-efficacy • Improved interest/ self-enjoyment. • Reduced BMI • Reduced waist circumference
Jenkinson, Doherty, Avery, Read, Taylor, Sach, Silcocks and Muir (24)	N = 389 Age = >40 Mean BMI = 33.6	• Duration = 24 months • Session length = 20-30mins (daily) • Exercise mode = Resistance training • Intensity = increase from manageable repetitions to 20 repetitions per strengthening exercise	• Reduce knee pain • Improve knee function

Ross, Dagnone, Jones, Smith, Paddags, Hudson and Janssen (21)	N = 52 Mean Age = 44.5 Mean BMI = 31.3	• Duration = 12 weeks • Session length = time to expend 700 kcal (daily) • Exercise mode = Treadmill (aerobic) • Intensity = no greater than 70% peak O_2 uptake	• Decreased body weight • Improved peak oxygen • Decreased total fat • Reduced abdominal subcutaneous, visceral, and visceral fat–to–subcutaneous fat ratios
Svensson, Eek, Christiansen and Wisén (22)	N = 110 Mean Age = 46 Mean BMI = 43.1	• Duration = 16 weeks • Session length = 1 hour (3 x weekly) • Exercise mode = cycle, rowing machine, treadmill, cross-trainer (aerobic) + resistance training • Intensity (aerobic) = 6-minute intervals at HR > 90%max. 30s pause between each bout • Intensity (resistance) = 2-minute intervals at > 90% HRmax. 30s pause between each bout	• Increase in Physical Summary Scale, Physical Functioning, and General Health • Increase in Vitality • Improved physical summary scales • Improved mental summary scale • Physical functioning • Increased aerobic capacity • Reduced body weight
Utter, Nieman, Shannonhouse, Butterworth and Nieman (28)	N = 91 Mean Age = 45.6 Mean BMI = 32.9	• Duration = 12 weeks • Session length = 45 minutes (5 x weekly) • Exercise mode = walking (aerobic) • Intensity = 60-80% HRmax	• Increased VO_2max

Note. BMI: Body Mass Index. HRR: Heart Rate Reserve. BF%: Body Fat Percentage. HIT: High Intensity Training. HRmax: Heart Rate Max. CSA: Cross-sectional Area. VO_{2max}: Maximal Oxygen Uptake and Utilisation. 1RM: One Repetition Maximum. WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index. HRQoL: Health Related Quality of Life. Kcal: Kilocalorie. HR: Heart Rate.

Table 2. Description of included studies with osteoarthritic cohort (N=8)

Study	Participants	Exercise Prescription	Outcome/Results
da Silva, de Melo, do Amaral, Caldas, Pinheiro, Abreu and Brito Vieira (12)	N = 30 Age = >18 Mean BMI = 29.33	• Duration = 8 weeks • Session length = 45 minutes (2 x weekly) • Exercise mode = Resistance training • Sets:Reps = 3x10; isometric holds = 3 x 10s	• Improvement in Lequesne total score • Improvement in physical function, bodily pain, general health, vitality, and role emotional subdomains of SF-36 • Improved chair stand • Improved timed up and go score • Improved 6-minute walk distance
Huang, Yang, Lee, Chen and Wang (20)	N = 140 Age = 40-77	• Duration = 8 weeks • Exercise mode = Resistance training (3 x weekly) • Intensity = 60% of the average peak torque was selected as the initial dose of isokinetic exercise; 5 seconds of rest between sets; 10 seconds of rest between different modes of training; 10 minutes of rest between right and left knee training.	• Increased muscle peak torques • Significantly reduced pain and disability
Krauss, Steinhilber, Haupt, Miller, Martus and Janssen (27)	N = 209 Age = 18-85 Mean BMI = 27.18	• Duration = 12 weeks • Session length = 40-90 minutes (3 x weekly) • Exercise mode = Resistance training • Intensity = varied (15-30 repetitions, some isometric holds for certain exercises)	• Improved pain symptoms • Improved physical function.
Lim, Tchai and Jang (31)	N = 75 Age = ≥50 Mean BMI = 27.73 Mean BF % = 33.97	• Duration = 8 weeks • Session length = 40 minutes (3 x weekly) • Exercise mode = Aquatic Exercise (aerobic + resistance training) • Intensity (aerobic) = 65% HRmax • Intensity (resistance) = 40-60% 1RM	• Reduced WOMAC score • Improved SF-36 (mental component scale)
O'Reilly, Muir and Doherty (18)	N = 191 Age = 40-80	• Duration = 6 months • Exercise mode = Resistance training (daily) • Intensity = increase from manageable repetitions to 20 repetitions per strengthening exercise	• Reduction in pain • Reduction in VAS scores • WOMAC score reduced • Increased quadriceps strength

Peterson, Kovar-Toledano, Otis, Allegrante, Mackenzie, Gutin and Kroll (32)	N = 102 Age = 40-89	• Duration = 8 weeks • Session length = 30 minutes (4 x weekly) • Exercise mode = Walking + resistance training • Intensity = low	• Increased walking distance • Increased stride length • Increased walking speeds
Teirlinck, Luijsterburg, Dekker, Bohnen, Verhaar, Koopmanschap, van Es, Koes and Bierma-Zeinstra (15)	N = 203 Age = ≥45 Mean BMI = 27.5	• Duration = 3 months • Frequency = maximum 12 sessions followed by 3 booster sessions • Exercise mode = Resistance training + aerobic exercise	• Reduced HOOS pain and HOOS function at 3 months
Thomas, Muir, Doherty, Jones, O'Reilly and Bassey (19)	N = 600 Age = ≥45 Mean BMI = 28	• Duration = 2 years • Session length = 20-30 minutes (daily) • Exercise mode = Resistance Training • Intensity = Graded exercise bands to provide increased resistance over time. Repetitions were maxed at 20 per leg	• Reduced knee pain • Reduced stiffness • Reduced WOMAC score • Improved function • Increased strength

Note. BMI: Body Mass Index. SF-36: 36-Item Short Form Health Survey.BF%: Body Fat Percent. HRmax: Heart Rate Maximum. 1RM: One Repetition Maximum. VAS: Visual Analog Scale. WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index. HOOS: Hip disability and Osteoarthritis Outcome Score.

Table 3. Average Downs and Black scores for included studies

Reference	Downs & Black Score	Downs & Black Category
Alves et al (2009).	21	Fair
Aradet al (2015).	15	Poor
Bhutani et al (2013).	20	Fair
Blue et al (2017).	16	Poor
Chiu et al (2017).	18	Fair
Christensen et al (2015).	22	Fair
da Silva et al (2015).	21	Fair
de Rooij et al (2017).	28	Good
Domene et al (2016).	17	Poor
Herring et al (2014).	14	Poor
Huang et al (2005).	12	Poor
Jenkinson et al (2009).	21	Fair
Krauss et al (2014).	22	Fair
Lim et al (2010).	20	Fair
O'Reilly et al (1999).	19	Fair
Peterson et al (1993).	18	Fair
Ross et al (2000).	16	Poor
Svensson et al (2017).	17	Poor
Teirlinck et al (2016).	26	Good
Thomas et al (2002).	23	Good
Utter et al (1998).	20	Fair

4. Discussion

The findings of the present systematic review support the existence of a natural overlap in exercise prescribed the osteoarthritic and obese cohorts. Moderate, vigorous, and high intensity aerobic training as well as resistance training were used in both obesity and OA studies, resulting in significant improvements in weight or pain outcomes. Similarities within exercise prescription parameters (i.e. intensity, frequency, duration, mode) suggest that there is a common and effective exercise prescription for concurrently managing both weight and musculoskeletal pain or dysfunction (Figure 2).

4.1 Recommended Intensity

Exercise intensity was similar among interventions for both obesity and OA studies. The most effective exercise intensity for weight loss was seen in a study by Ross et al (21), which showed an average weight loss of 7.5kg when aerobic exercise was completed at an intensity no greater than 70% VO_{2peak} until 700kcal had been expended. Similar exercise intensities were used by Chiu et al (26), resulting in similar weight loss (6.72 kg) after aerobic exercise was completed 3 times each week at 40-80% of heart rate reserve. Higher intensity training was also associated with, significant improvements in pain and function in some studies (17, 31). Specifically, studies reported reductions in WOMAC score (17, 31) and the physical subsection of the SF-36 survey (31), and pain scales associated when aerobic exercise was completed at 50-80% maximal heart rate/VO_{2max}.

Several studies included resistance training, either as a supplement to aerobic training, or independently prescribed. For all resistance training protocols, the intensity was similar (3 sets of 8-12 repetitions at 40-80% 1-repetition maximum) and positive results were seen for both weight and pain outcomes. For example, Lim et al (31) included resistance training in their intervention (alongside aerobic training) and witnessed a significant reduction in both BMI and BF% as well as improvements in WOMAC and subsections of SF-36.

A reduction in weight from exercising at the above intensities (40-80% VO_{2max}) can be explained by the fact that maximal fat oxidation occurs within the range of 50 and 70% VO_{2max} (34). And while research has shown that there is significantly greater fat oxidation at 65% VO_{2max}, there is no difference between fat oxidation at lower (25% VO_{2max}) and higher (85% VO_{2max}) intensities (35). Because sedentary individuals do not often complete moderate intensity exercise, the increase to even the lower ranges of fat oxidation (i.e. 50% VO_{2max}) can result in modest improvements in body composition with less risk of inducing pain or discomfort. Exercise intensity can then be progressed to higher percentages of VO_{2max} to achieve the greatest rate of fat oxidation. However, it is unnecessary to train these cohorts at intensities more vigorous than 80% VO_{2max} as the fat oxidation reduces and the additional intensity could increase risk of injury or pain in either group. Within resistance training, it is widely accepted that fewer repetitions with a heavier load is the optimal intensity to increase muscular strength (36). However, training at a high percentage of 1RM may result in adverse health outcomes for sedentary individuals. Increases in strength can still occur with more moderate loads so it is recommended to begin at the lower end (40% 1RM) and gradually progress the load used as required.

While specific intensities for both aerobic and resistance training were not mentioned in a systematic review of exercise guidelines for osteoarthritic populations (37), weight management recommendations aligned with the studies included in this review. Specifically, it is recommended that moderate aerobic exercise intensity (65-80% VO_{2max}) be prescribed to obese individuals (38). Recommendations for the optimal intensity for resistance training for obese populations is currently unclear as resistance training has not been shown to be effective in significantly reducing weight (38).

4.2 Recommended Frequency and Duration

Exercise frequency was similar between the different studies, irrespective of a focus on obesity or OA. The most effective frequency for weight loss was exercise performed daily, as shown by Ross et al (21). However, daily exercise may be too intensive for highly sedentary individuals just beginning to be physically active. Exercise frequency of 2-3 times per week was the most common frequency used in the studies included in this review regardless of focus on obesity or OA (12-14, 17, 20, 22, 23, 25-27, 29-31). These studies reported significant reductions in weight or musculoskeletal pain when obese or osteoarthritic populations exercised 2-3 times per week. Exercise duration between studies did not vary greatly. Exercise sessions typically lasted between 30-60 minutes with the exception of Ross et al (21), where session length was determined by the time to expend 700kcal.

In exercise interventions lasting less than 16 weeks, a linear dose-response relationship occurs between exercise frequency and weight loss (39). Additionally, increased exercise frequency has been associated with the prevention of weight gain over time (39). Therefore, it could be recommended that obese individuals should perform exercise 2-3 times per week with the goal of increasing this frequency over time to maintain the weight loss. There is not a clear dose-response relationship for OA; however, high frequency exercise may increase risk of joint trauma/injury (39). Thus, the exercise frequency of 2-3 times per week appears to be effective in safely achieving exercise benefits for both populations.

Exercise frequency and duration recommendations are suggested to be 150-250 minutes per week for weight loss (38). The majority of reviewed studies (13, 18, 19, 21, 22, 24, 26-

28) prescribed exercise (60 minutes, 3 times per week) that fit within these recommendations. The exception would be research by de Rooij et al (17), where a lesser frequency still resulted in significant benefits for the outcome measures. The improvements to pain and physical functioning (17) suggest that beginning an exercise prescription at a reduced frequency would still yield desired health benefits. Sedentary individuals could then progress to higher frequencies as fitness and exercise capacity increase.

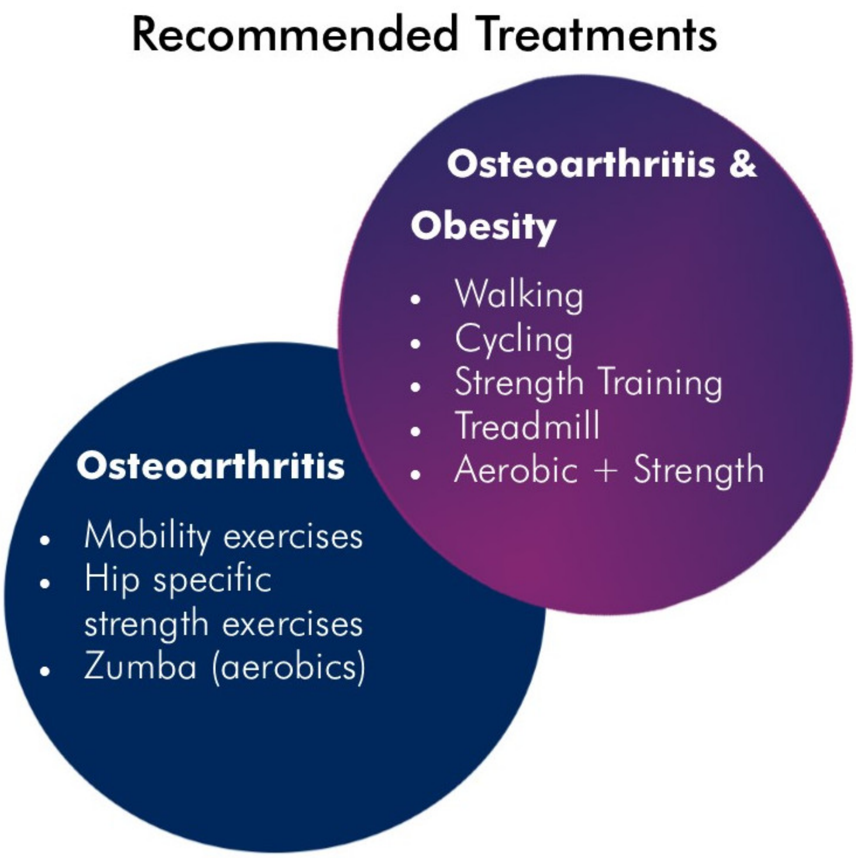

Figure 2. Recommended exercise modes

4.3 Exercise Mode

Aerobic training and/or resistance training were used in all reviewed studies, either in combination or independently prescribed. Interestingly, exercise modes with an aerobic component did not differ greatly between interventions for obesity or OA. Specifically, exercise conducted on treadmills, stationary bikes, rowing ergometers, or cross-trainers all yielded significant improvements in weight status or musculoskeletal pain. Resistance training was included mainly in OA studies (either alongside aerobic training or independently prescribed) and primarily focused on strengthening the quadriceps muscles or muscles around the hip. Resistance exercises included both bodyweight and the use of resistance machines. Where resistance training was included in obesity studies, the exercises primarily addressed multiple joints and used resistance machines.

Only one study included in this review investigated the effect of aquatic exercise. Lim et al (31) compared aquatic exercise to land based exercise and reported significant improvements in musculoskeletal pain and function, and significant reductions in both BMI and BF% when compared to baseline measurements for both interventions. The aquatic based exercise group had a significantly greater change in pain interference when compared to the land based group. A reduction in pain interference suggests that aquatic exercise is a more tolerable form of exercise compared to land based exercise and results in significant improvements in weight status. The intervention used by Lim et al resulted in the greatest reduction in WOMAC scores compared to the other studies included in this review and highlights the potential efficacy of aquatic exercise for OA prevention amongst obese populations.

Current guidelines for exercise for osteoarthritic populations recommend that aerobic exercise should be low-impact and used in combination with strengthening exercises for the knee/ hip, reducing the resistance if the individual is overweight (37). Thus, partial and non-weight bearing exercise are encouraged (37). Additionally, aquatic exercise is recommended as a low-impact exercise, (37) yet only one study included in this review featured aquatic exercise (31). It is possible that our observation of few studies including aquatic interventions may be related to the age restriction for our study, as older populations may be more likely to prefer aquatic exercise interventions secondary to pain during land-based exercises (citation)

Current exercise guidelines for weight and OA management do not identify specific exercise modes, (37, 38) and future studies should evaluate the effect of mode on weight loss musculoskeletal pain. Nonetheless, based on the reviewed studies, a variety of aerobic modalities can be effective for weight and OA management. However, partial and non-weight bearing exercise such as cycling or aquatic exercise should be included when musculoskeletal pain is too severe. The aerobic exercise should be combined with multi-joint resistance training exercises, with a special focus on strengthening the muscles around affected joints should be prescribed.

6. Limitations

There were aspects of the search strategy that limited the scope of the presented findings. Specifically, the age range, and co-morbidities associated with obesity limited the amount of studies that were included. Additionally, a meta-analysis was not completed because of the vast differences in populations, interventions, and methods that may have resulted in the average effect across included studies meaningless.

5. Conclusion

Obesity and OA share several characteristics, one of which is a management plan that must include exercise. Based on this review, there does appear to be evidence for an overlap in exercise prescription that ultimately benefits both cohorts. Initially, exercise intensity should be prescribed at the lower range of VO_{2max} (40-50%) with the intention to progress to 60-80% VO_{2max} as exercise tolerance increases. Exercise is most effective when performed 3 times per week for at least 30-60 minutes and progressed as the individual's capacity increases. Exercise mode can include full (i.e. treadmill) or partial (i.e. cross-trainer, rowing ergometer, stationary bike, aquatic) weight bearing exercises, depending on the need of the individual. Resistance training should begin at a lower percentage of 1-repetition maximum and increase gradually, focusing on multi-joint movements and strengthening of the muscles surrounding the affected joints. By identifying commonalities in the exercise prescription of two significant cohorts, this review has suggested an effective starting point in ensuring the greatest benefits from exercise are achieved with minimal impact on joints.

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