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A Comprehensive Review of the Effectiveness of Different Exercise Programs for Patients with Osteoarthritis

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Abstract

Exercise is recommended as a first-line conservative intervention approach for osteoarthritis (OA). A wide range of exercise programs are available, and scientific evidence is necessary for advising patients with OA on the optimal treatment strategy. The purpose of this review is to discuss the effectiveness of different types of exercise programs for OA based on trials, systematic reviews, and meta-analyses in the literature. Publications from January 1997 to July 2012 were searched in 4 electronic databases using the terms osteoarthritis, exercise, exercise program, effectiveness, and treatment outcome. Strong evidence supports that aerobic and strengthening exercise programs, both land- and water-based, are beneficial for improving pain and physical function in adults with mild to moderate knee and hip OA. Areas that require further research include examination of the long-term effects of exercise programs for OA, balance training for OA, exercise programs for severe OA, the effect of exercise programs on progression of OA, the effectiveness of exercise for joint sites other than the knee or hip, and the effectiveness of exercise for OA by such factors as age, gender and obesity. Efforts to improve adherence to evidence-based exercise programs for OA and to promote the dissemination and implementation of these programs are crucial.

Keywords

osteoarthritis; exercise; physical activity; treatment outcome; effectiveness

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Conflict of Interest Statement

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INTRODUCTION

Osteoarthritis (OA) is the most common form of arthritis and the leading cause of disability among older adults in the United States.[1] Osteoarthritis is associated with significant pain, and it limits mobility, basic daily activities, and quality of life.[2–4] According to data from 2003 to 2005, at least 27 million Americans have OA.[5] Over the next few decades, substantial rises are expected in the incidence, health impact, and economic consequences of OA, largely due to the aging of the US population and the obesity epidemic,[6,7] because older age and excess body weight are both well-recognized risk factors for the development of OA, especially knee OA. The burden of knee OA alone is particularly high and is on the rise.[8,9] Approximately 600 000 primary total knee arthroplasty (TKA) procedures, a common procedure in patients with severe knee OA, are performed annually in the United States, and annual TKA volume increased 161.5% in the US Medicare population between 1991 and 2010.[8] Furthermore, in 2006, 496 000 hospital discharges and $19 billion in hospital charges were due to knee OA.[9]

Treatments available for OA include pharmacological therapies, intra-articular injections, surgical procedures, and conservative interventions, such as physical therapy, braces and devices, and exercise. Professional rheumatologic and orthopedic organizations recommend conservative interventions as a fundamental strategy for management of mild to moderate OA,[7,10–16]; oftentimes, these conservative approaches need to be combined with pharmacological and surgical treatments for optimal disease management. All of the interventions previously described can help reduce pain associated with OA, and an important advantage of nonpharmacological/nonsurgical approaches, particularly those interventions that include exercise, is their direct effect on improving physical function.[10,15,17]

Although increased risk of OA has been associated with joint injury suffered in sport,[18] physical activity is beneficial for joint tissues and can help decrease symptoms and improve function.[19] Accordingly, physical activity has been noted as a central component in the Centers for Disease Control and Prevention (CDC) and Arthritis Foundation's 2010 publication, *A National Public Health Agenda for Osteoarthritis*.[7] Exercise programs for OA may be land- or water-based and include activities focused on endurance (eg, walking), range-of-motion/flexibility, strengthening, balance, or any combination of these components.

This article will discuss the effectiveness of exercise programs for OA based on a comprehensive review of the literature and examine the effectiveness of exercise programs by type of exercise and severity of OA. Although exercise programs for OA may benefit many affected joint sites, research in this area primarily has examined the effectiveness of programs for the knee and hip, and therefore, these joints will be the predominant focus of this article. Several systematic reviews of the effectiveness of different exercise programs for patients with knee and hip OA have been published. The intent of this manuscript is to summarize and extend those previous reviews with more recently published work and to cover a wider range of exercise types than reported in other more recent reviews. To build the overall picture, however, material previously reviewed will be included. The emphasis of

this paper will be on randomized controlled trials (RCTs), as they can provide stronger evidence than other study designs of the effectiveness of intervention programs.

MATERIALS AND METHODS

A literature search of publications from the past 15 years (January 1997 through July 2012) was conducted within Pubmed/Medline, the Cochrane Library, the Physiotherapy Evidence Database, and the Cumulative Index to Nursing and Allied Health Literature using the terms osteoarthritis, exercise, exercise program, effectiveness, and treatment outcome. Although a systematic approach was not used for this article, titles and abstracts were reviewed for identified articles by 2 of the authors (YMG and DJC) to determine if they were specific to OA, had a clearly defined exercise program, and examined the effectiveness of the program. English-language RCTs and systematic reviews of exercise programs for OA were included, and pharmacological and surgical intervention studies of OA (such as total joint replacement) that included exercise programs were excluded. Full text was obtained for articles that met these criteria. The initial search strategy identified 443 potentially relevant publications. Duplicates (72) and articles that did not meet inclusion criteria after examining titles and abstracts (322) or reviewing the full text (10) were removed, leaving 39 articles included in this review.

Land-Based Exercise Programs for OA

Mixed Land-Based Exercise Programs—Land-based exercise programs have included aerobic or endurance activities (eg, walking and cycling), strength training with and without weights, and balance training. Three systematic reviews of RCTs have broadly examined the effects of land-based exercise programs on pain and physical function related to knee and hip OA (Table 1). The results of a systematic review of 5 RCTs comparing land-based exercise with nonexercise among people with hip OA showed only small improvement in pain (standardized mean difference [SMD], 0.38; 95% CI 0.09–0.67),[20,21] but no beneficial change in self-reported function (SMD, −0.02; 95% CI −0.31 to 0.28). The authors commented that the limited number and small sample size of the included RCTs, along with the heterogeneity of the studies, minimize the interpretability of these results.

Fransen and McConnell[22,23] reviewed 5 electronic databases from January 1996 through December 2007 to examine a range of land-based exercise programs for knee OA, including walking, strengthening, and balance activities. Thirty-two RCTs studies were included in the review, with a total of 3616 participants with knee pain data and 3719 participants with self-reported physical function data. Results of the meta-analysis showed effectiveness of land-based exercise programs with a SMD of 0.40 (95% CI, 0.30–0.50) for pain and 0.37 (95% CI, 0.25–0.49) for physical function. The authors emphasize that although these effect sizes appear small, they are in fact comparable with estimates reported for simple analgesics and nonsteroidal anti-inflammatory drugs (NSAIDs) for the treatment of knee pain. Notably, interventions that involved a greater number of directly supervised sessions (≥ 12 visits) were associated with greater improvements in knee pain and physical function.

A meta-analysis by Roddy et al[24] compared the efficacy of aerobic walking (3 studies), home-based quadriceps strengthening programs (9 studies), and aerobic walking with home-

based strengthening exercises (1 study) in patients with knee OA. In an analysis that compared aerobic walking study arms with nonexercise only, the weighted pooled effect size of all 4 studies for reduction in pain was 0.52 (95% CI, 0.34–0.70). For the quadriceps strengthening compared with nonexercise study arms, the weighted pooled effect size for reduction in pain was 0.32 (95% CI, 0.23–0.42) and for improved physical function was 0.32 (95% CI, 0.23–0.41). Interestingly, an indirect comparison of aerobic walking and quadriceps strengthening programs suggested no apparent advantage of 1 program over the other regarding pain and disability.

Recently, Hurley et al[25] published results on their RCT of 418 individuals with chronic mild, moderate, or severe knee pain/OA; 278 people participated in the Enabling Self-Management and Coping of Arthritic Knee Pain Through Exercise (ESCAPE-knee pain) program, and 140 people participated in a usual care control group. The ESCAPE-knee pain program was a physiotherapist-led program that met twice weekly for 6 weeks at an outpatient physiotherapy gym and included 15 to 20 minutes of discussion of coping strategies and 30 to 45 minutes of individualized, progressive strengthening and balance exercises.[25,26] At the end of 6 weeks, no further treatment was provided, and participants were discharged with a home exercise regimen, provided with information about local exercise facilities, and advised to engage in a simple activity (eg, walking).[25,26] After the 6-week program, physical function was significantly better in the exercise group than the control group (mean difference in Western Ontario and McMaster Universities Arthritis Index [WOMAC] function, −5.5; 95% CI, −7.8 to −3.2). Over the 30-month follow-up, initial gains in physical function declined, but better physical function was maintained in the exercise group compared to the control group (difference in WOMAC function, −2.8; 95% CI, −5.3 to −0.2).

Aerobic Programs—The Fitness Arthritis and Seniors Trial (FAST) examined aerobic and resistance exercise in 439 adults who were aged > 60 years of age with radiographic knee OA and pain (see Strength Training Programs section for resistance exercise description and results).[27] Participants were randomized to aerobic exercise, resistance exercise, or a health education control group, with 365 participants completing the trial. The aerobic program consisted of a 3-month facility-based walking program that met 3 times per week, followed by a 15-month home-based walking program. Compared with participants in the control group, participants in the aerobic exercise group demonstrated reduced mean scores on the physical disability questionnaire (1.71 vs 1.90 units, $P < 0.001$) and the knee pain questionnaire (2.1 vs 2.4 units, $P = 0.001$), and better performance on physical function tasks of the 6-minute walk test (1507 vs 1349 ft, $P < 0.001$), time to complete stair climbing task (12.7 versus 13.9, p=0.05), time to lift and carry 10 lbs (9.1 vs 10.0 sec, $P < 0.001$), and car transfer time (8.7 vs 10.6 sec, $P < 0.001$).

A small study of 39 adults suggests that cycling may be a useful aerobic exercise option for people with knee OA.[28] Participants were randomized to either a high- (30% heart rate reserve) or low-intensity (40% heart rate reserve) stationary cycling exercise program for 10 weeks, completing 25-minute sessions, 3 times per week. Both groups showed reduced overall pain based on the pain subscale of the Arthritis Impact Measurement Scale 2 (weighted mean difference [WMD], −0.11; 95% CI, −1.32 to 1.10) , improved timed chair

rise (WMD, 0.30; 95% CI, −4.09 to 4.69) and distance walked in 6 minutes (WMD, 13.68, 95% CI, −60.12 to 87.48), and improved aerobic capacity based on peak oxygen consumption (WMD, −262.02; 95% CI, −681.19 to 157.15), with no significant differences between the groups. Interpretations of the study findings are limited by the sample size and lack of control group.

Strength Training Programs—Liu and Latham[29] assessed the effects of progressive resistive training (PRT) (ie, progressively increasing the load during the training program in order to maintain or increase the exercise intensity) in older patients (mean age for included studies was 60 years or older) and attempted to identify adverse events (Table 1). Eight electronic databases were searched, as well as reference lists from articles and reviewed conference abstracts. Of the 121 trials reporting physical outcomes of progressive resistance training for older people, 6 studies were of participants with knee or hip OA (mean ages 64.5–79.6 years). Progressive resistive training was performed 2 to 3 times per week at high intensity, and OA pain reduction was observed after PRT compared with nonstrength training control groups (SMD, −0.30; 95% CI, −0.48 to −0.13).

Latham and Liu[30] examined PRT for OA in 7 studies in which participants had knee OA only[27,31–36] and 1 study in which participants had hip and knee OA (Table 1).[37] Compared with nonstrength training control groups, results for the PRT programs showed moderate effect sizes for reduced pain (SMD, −0.35, 95% CI, −0.52 to −0.18), improved function (SMD, 0.33; 95% CI, 0.18–0.49), and improved leg extensor strength (SMD, 0.33; 95% CI, 0.12–0.54). An example of 1of these studies is the large Fitness Arthritis and Seniors Trial (FAST), which had a resistance training group.[27] The resistance training program consisted of a 3-month facility-based program meeting 3 times per week to perform 2 sets of 12 repetitions of 9 exercises, followed by a 15-month home-based program. The exercises included both upper and lower body maneuvers using dumbbells and cuff weights. Compared with participants in the control group, participants in the resistance exercise group demonstrated reduced mean scores on the physical disability questionnaire (1.74 vs 1.90 units, $P = 0.003$) and the knee pain questionnaire (2.2 vs 2.4 units, $P = 0.02$) and improved performance on physical function tasks (ie, greater distance walked for the 6-minute walk test [1406 vs 1349 ft, $P = 0.02$], faster time on a lifting and carrying 10 lbs task [9.3 vs 10.0 sec, $P = 0.001$], and faster time to get in and out of a car [9.0 vs 10.6 sec, $P = 0.003$]).

Pelland et al[38] performed a systematic review of 21 studies to assess the effects of PRT on adults with OA (Table 1). Exercise programs included concentric, eccentric, isometric, isokinetic resistance, and whole body functional strengthening. Overall, strength, pain, function, and quality of life improved with these programs. The authors recommended that exercise programs should include joint-specific strengthening along with general strength, flexibility and functional exercises, and that the exercise program should be progressed. Furthermore, they suggested that the type of strengthening does not seem to differ in effectiveness.

Another advantage of PRT programs is that they appear to promote increased levels of moderate- and vigorous-intensity physical activity. In an RCT of 171 men and women with

mild knee OA, participants were randomized to a resistive training group, a self-management group, or a group who participated in both interventions.[39] Accelerometers were used to track activity of each participant for a period of 5 to 7 days at baseline and 3- and 6-month follow-up visits. By 3 months, both the resistive training and self-management groups had increased their physical activity levels (18% and 22%, respectively), but only the resistive training group maintained that increase at 9-month follow-up. Interestingly, in another report on this same trial,[40] all 3 interventions showed marked improvements with physical function measures (Cohen's d, 0.59–1.00), knee pain (Cohen's d, −0.51), and disability (Cohen's d, −0.55), with no significant differences between groups.

An RCT of 142 patients with knee OA demonstrated that a home-based quadriceps strengthening program may be as effective as the use of NSAIDs for improved pain, stiffness, physical function, and quality of life outcomes during an 8-week intervention period.[41] The exercise program was simple, involving 20 repetitions of a slow knee extension movement performed 4 times daily. The authors emphasized that the effectiveness of this exercise depended on patient adherence, which the investigators encouraged through instructional documentation, regular visits to check patient compliance and progress, and a daily treatment record of exercise and medication use to be kept by the patient.

Jenkinson et al[42] studied the effectiveness of a dietary intervention, knee strengthening exercise, or both in an RCT for the management of knee pain and function in a group of 389 overweight and obese men and women aged ≥ 45 years. The interventions were implemented for 2 years through home visits. At the 24-month follow-up visit, knee pain based on WOMAC improved significantly in the exercise groups compared with those in the nonexercise groups (mean difference, −0.91; 95% CI, −1.66 to −0.17), a change not seen in the dietary versus nondietary groups (mean difference, −0.08; 95% CI, −0.91 to −0.75).

Most trials to date have studied knee strengthening exercises as a treatment for knee OA, but 1 RCT examined a hip strengthening program as a treatment for medial knee OA.[43] The program consisted of a 12-week physiotherapist-supervised home-exercise program of hip abductor and adductor strengthening exercises, and participants were randomized to the hip strengthening group (N = 39) or a control group without intervention (N = 37). Pain, physical function, and hip and knee strength measures were significantly improved in the exercise group compared with the control group (eg, WOMAC pain-adjusted mean difference, −2.12 [95% CI, −3.24 to −1.00], WOMAC function-adjusted mean difference, −06.17 [95%CI, −9.41 to −2.93]), but the primary outcome of peak knee adduction moment during 3-dimensional gait analysis did not change (adjusted mean difference, 0.13 [95% CI −0.07, 0.34]). In this study, hip strengthening exercises did not appear to modify the biomechanical mechanism of medial knee OA (ie, medial knee loading), but appear helpful in symptom management of the disease.

High versus Low Resistance Training Programs: High-resistance (high load and low repetitions) and low-resistance (low load and high repetitions) exercise training programs were examined in a study of 102 participants with mild to moderate knee OA.[44] Participants were randomized to 8 weeks of high-resistance exercise, low-resistance exercise, or no exercise (control group). Using a leg press machine, the initial intensity for the high-

resistance exercise group was 60% of the 1-repetition maximum for 3 sets of 8 repetitions, and the initial intensity for the low-resistance group was 10% of the 1-repetition maximum for 10 sets of 15 repetitions. At follow-up, pain, function, walking time, and muscle torque improved in both exercise groups, with no statistically significant differences between them, although effect sizes were slightly greater for high-resistance (range, 0.64–3.13) than for low-resistance exercise (range, 0.51–2.70). The authors suggested the clinical importance of including high-resistance exercise in a comprehensive rehabilitation program for knee OA, not only to improve pain and physical function outcomes, but also in the interest of time-efficiency; the high-resistance exercises in this study required 20 minutes fewer per session than the low-resistance exercises. However, it should be noted that 3 participants in the high-resistance group discontinued the study due to severe knee pain, while all participants in the low-resistance group completed the study.

High versus Low Speed Power Training Programs: A recent pilot study of older adults with knee OA examined the effect of high-speed power training on pain and physical function.[45] Twelve participants were randomized to the high-speed power training program, 10 to the slow-speed strength training group, and 11 to a control group. The 2 exercise groups completed their respective programs 3 times a week over 12 weeks, and at follow-up assessment, the improvements in strength and muscle power were comparable between the 2 groups compared with the control group. Muscle speed (leg press velocity at peak power) improved with high-speed power training compared with slow-speed and control groups. Both high-speed and slow-speed training groups showed improved pain and physical function, but no more than the improvements noted in the control group.

Dynamic versus Isometric Resistance Training Programs: In 102 participants with knee OA, Topp et al[36] compared a dynamic resistance training program (exercises through the range of motion using an elastic band for resistance) with an isometric training program (exercises at specific joint angles without joint motion with the muscle contracting against a maximum-resistance elastic band). Compared with a nonexercise control group, both groups demonstrated relief of knee pain (12%–14% improvement on the WOMAC pain subscale) and faster times with ascending and descending a flight of stairs and getting up and down from the floor (13%–23% improvement) after 16 weeks of training. However, changes in these measures did not differ significantly between the dynamic and isometric training groups.

Balance and Neuromuscular Training—Silva et al[46] conducted a systematic review of exercise programs for women with knee OA that used balance as an outcome (Table 1). Nine RCTs were identified, with 8 considered to have quality evidence, and the exercise programs ranged from aerobic and strength training,[47,48] aquatic physical therapy,[49] Tai Chi,[50] vibrating platform exercise,[51] balance exercises,[52] and strength training with controlled or uncontrolled weights.[53] Although the methods and intervention approaches for these studies varied greatly, most demonstrated improved balance after an exercise program. The authors suggest that exercise programs can benefit balance for women with knee OA.

Vibration Training Programs: In vibration training, an individual performs exercises while on a machine that vibrates. An RCT by Trans et al[51] examined whole-body vibration training on a stable platform, vibration training on a balance board, and no-exercise control in 52 women with knee OA. Improvements were noted in muscular power for the stable-platform vibration training group (WMD, 7.6 Newton-meters [Nm]; 95% CI, 3.5–11.6) versus the control group (isokinetic knee extension) (isometric peak torque knee extension, 11.9 Nm; 95% CI, 1.9–22.0) and in proprioception (ability to sense position and movement of the body) (WMD, −0.59 sec; 95% CI, −1.13 to 0.05) for the balance board vibration training versus control. In a more recent RCT of whole body vibration, Avelar et al[54] evaluated vibration training with squat training compared with squat training alone on functional performance and self-report of disease in older adults (n = 23) with knee OA. No significant differences were noted in functional performance (Berg Balance Scale score, timed get-up-and-go test, chair stand test, 6-minute walk test) or WOMAC scores between the groups in this small study, but both exercise groups showed improvement in these outcomes compared with their baseline status (eg, 6-minute walk test pre-vibration training, 424 m vs 448 m after training, $P < 0.05$; pre-squat training, 394 sec vs 421 sec post-training, $P < 0.05$).

Tai Chi Programs: Tai Chi is a form of exercise that includes slow, continuous movements and postures that promote balance, flexibility, and strength. The results of several RCT studies indicate the potential for Tai Chi to improve function in women with OA. Ni et al[55] examined the effectiveness of a 24-week Tai Chi program on physical function in 35 Chinese women ages 55–75 years (mean=63 years) with knee OA. Compared with the control group (wellness education and stretching), the participants in the Tai Chi group had statistically significant improvements in total WOMAC score (6.18 vs 1.71); WOMAC pain (1.36 vs 0.07), stiffness (0.66 vs 0.05), and function subscales (6.17 vs 1.72); the 6-minute walk distance (32.43 vs 16.76 m); and the stair climb time (2.27 vs 0.27 sec).

Song et al[56] conducted a 6-month RCT of Tai Chi on knee muscle strength, bone mineral density, and fear of falling in older women with knee OA. Compared with the control group (n = 35), women randomly assigned to the Tai Chi intervention (n = 30) had significantly greater knee extensor endurance (mean change, 36.4 in Tai Chi group vs 1.1 W/kg in control group, P =0.01) and greater bone mineral density in the proximal femoral neck (mean change of 0.09 in T-score for Tai Chi group vs −0.10 in control group, $P < 0.001$). Fear of falling during daily activities decreased in the Tai Chi group compared with the controls (mean change −2.40 in Tai Chi group vs 0.66 in control group, $P = 0.01$). Knee extensor and flexor strength did not differ significantly between the groups at 6 months.

In an RCT by Fransen et al,[57] 56 participants in a 12-week Tai Chi class showed mean improvements of 5.2 (95% CI, −0.8 to 11.1) for pain and 9.7 (95% CI, 2.8–16.7) for physical function scores compared with a waiting-list control group of 41 participants. These improvements continued through the 24-week follow-up visit. An RCT of 40 individuals with symptomatic tibiofemoral OA demonstrated improved pain, physical function, self-efficacy, depression, and health-related quality of life after 12 weeks of a 2-session-per-week Tai Chi program compared with an attention control program of stretching and

education.[58] Larger, high-quality studies are needed to confirm the effectiveness of Tai Chi for OA.

Proprioceptive Exercise Programs: Pathologies, such as OA, may affect one's ability to sense joint position and movement. Proprioceptive exercises aim at improving detection of where the body is in space. Smith et al[59] conducted a recent systematic review and meta-analysis to examine effectiveness of proprioceptive exercises for knee OA (Table 1). Seven RCTs with moderate methodological quality, involving a total of 203 males and 357 females (mean age, 63 years), were included in the analysis.[47,52,53,60–63] Compared with nonexercise control groups, proprioceptive exercise groups showed significantly better functional outcomes after 8 weeks of intervention (mean difference in WOMAC physical function score, −12.19; 95% CI, −15.67 to −8.71). Self-reported physical function did not differ between proprioceptive and general nonproprioceptive exercise programs (mean difference in WOMAC physical function score, 0.59; 95% CI, −2.12 to 3.29), and joint position sense was better after the proprioceptive exercises (mean difference in joint position angulation error, −2.18; 95% CI, −2.70 to −1.66). Although current evidence for proprioceptive exercise training is based on a low number of small, short-term studies, initial reports suggest that there may be an advantage of adding proprioceptive training to an exercise regime for knee OA.

Water-Based Exercise Programs for OA

Water-based, or aquatic, exercise programs are offered to some patients with OA as an alternative to land-based, weightbearing programs because they are believed to involve less loading on the joints and, in turn, be better tolerated for individuals with severe or painful disease. Generally, the evidence supports the benefits for water-based programs for knee and hip OA, although long-term effects have not been documented.

In a systematic review by Bartels et al,[64] 6 RCTs of 800 adults total were included to examine the effectiveness and safety of aquatic-exercise interventions on the treatment of knee and hip OA.[37,65–69] Small-to-moderate effect sizes were noted for physical function (SMD, 0.26; 95% CI, 0.11 to −0.42) and quality of life (SMD, 0.32; 95% CI, 0.03–0.61).

In an RCT of a 12-week aquatic flexibility and strength training program for 38 adults with knee and hip OA, participants in the exercise program (n = 20) demonstrated significantly improved knee extension and hip flexion and extension flexibility, knee and hip strength in all planes of motion, and aerobic fitness compared with nonexercise controls (n = 18).[70] However, self-report of physical functioning (based on the Health Assessment Questionnaire, $P = 0.481$) and pain relief (based on a visual analog scale, $P = 0.280$) did not demonstrate statistically significant differences by group after intervention, although mean pain ratings did decline slightly over the 12-week period in the aquatic exercise group (52.2 at baseline to 43.5 at 12 weeks).

Water-Based versus Land-Based Exercises—Several studies have examined the effectiveness of water-based programs compared with land-based exercises. Lund et al[71] compared land-based (N = 25) and water-based exercise (N = 27) groups with a control group (N = 27) in a study of adults with knee OA. After completing the 8-week exercise

programs, no immediate effects were detected in either exercise group, but at 3-month follow-up, slight improvement in pain and strength was noted only in the land-based exercise group compared with the control. However, fewer adverse effects, such as discomfort, occurred in the water-based exercise group versus the land-based exercise group.

Batterham et al[72] conducted a systematic review and meta-analysis to determine whether the effect of exercise programs differed by whether they were land- or water-based in individuals with arthritis (Table 1). Five out of 10 RCTs included in the analysis examined only patients with OA, 2 examined those with OA or rheumatoid arthritis (RA), and 3 examined only those with RA. Although the parameters and quality of each study were not consistent, physical function and mobility outcomes did not differ considerably by type of program. The authors suggested that water-based programs may be a reasonable alternative for people with arthritis who have difficulty performing land-based programs due to pain or strength limitations.

Wang et al[73] conducted an RCT of 84 participants with knee OA from local community centers randomized to either a water-based exercise class that followed the Arthritis Foundation Aquatic Program or a land-based class that consisted of exercises from the Arthritis Foundation Exercise Program. After 12 weeks of each program performed for 60-minute sessions, 3 times per week, both forms of exercise resulted in statistically significant improvements in physical function (6 minute walk test; water-based $p<0.001$, land-based $p=0.003$) and knee-related quality of life (water-based $p=0.001$, land $p<0.001$), and interestingly, despite expectations that water-based exercise would be more beneficial for pain reduction, improvements in pain were comparable in the 2 groups.

In a 12-week RCT of 152 older adults with chronic symptomatic hip or knee OA, participants completed either a hydrotherapy class (n = 55) or Tai Chi class (n = 56) or were wait-listed to a control group.[74] Compared with the control group, participants in the hydrotherapy classes demonstrated improved mean changes in WOMAC pain (6.5; 95% CI, 0.4–12.7) and function (10.5; 95% CI, 3.6–14.5) subscale scores, and participants in the Tai Chi classes demonstrated improved mean changes in WOMAC pain (5.2; 95% CI, −0.8 to 11.1) and function (9.7; 95% CI, 2.8–16.7) subscale scores. The Short Form-12 Health Survey physical component summary score was higher for both treatment groups compared with the control group (hydrotherapy mean score change, 4.0; 95% CI, 0.8–7.2; Tai Chi mean score change, 2.1; 95% CI 0.2, 4.4). Compliance was better for the hydrotherapy than the Tai Chi classes (81% vs 61% attended at least half of the available 24 classes, respectively).

Water-based exercise also may be an effective treatment alternative for overweight and obese patients with knee OA. In a study by Lim et al,[75] obese adults from Korea with knee OA were randomized to an aquatic exercise program (n = 26), a land-based exercise program (n = 25) or a nonexercise control group. After 8 weeks of intervention, WOMAC scores improved similarly between the 2 exercise groups, and these improvements were statistically significant compared with the control group. A significant change in Brief Pain Inventory score was noted only for the aquatic exercise program group.

Mixed Water-Based and Land-Based Programs

Escalante et al[76] (Table 1) conducted a systematic review of 33 studies to examine the effects of land-based (ie, strength, Tai Chi, and aerobic), aquatic, and mixed exercise programs on pain in patients with knee and hip OA. All studies in this review used the pain subscale of the WOMAC as a pain outcome measure. Pooled effect sizes were moderate to high and statistically significant ($P < 0.05$) for Tai Chi (~ 0.75), aerobic (~ 0.5), and hydrotherapy (~ 0.5) programs, while strength (~ 0.50) and mixed program (~ 0.25) effect sizes were statistically nonsignificant. Exercise programs based on Tai Chi demonstrated statistically better improvements in pain than mixed exercise programs ($P < 0.05$).

Another systematic review by Escalante et al[77] examined the effectiveness and structure of exercise programs on functional aerobic capacity in individuals with hip and knee OA (Table 1). This included 19 RCTs and 1 non-RCT. The programs examined were both aquatic (ie, hydrotherapy)[37,49,68] and land-based interventions (ie, strength training,[27,37] Tai Chi,[55,58,78] aerobic programs,[27,79–81] and programs with multiple exercise components[82–89]). The highest pooled effect size was observed for the aerobic programs, followed by Tai Chi, mixed exercise, and hydrotherapy. The authors noted in both papers that the programs reviewed in this paper varied considerably based on duration of the programs, the duration and frequency of the sessions, and content of each program.

Exercise Programs for Severe OA

Most of the studies described previously include individuals with mild to moderate OA of knee and hip. Wallis and Taylor[90] conducted a systematic review and meta-analysis that examined the effectiveness of nonpharmacological and nonsurgical approaches for the treatment of severe knee and hip OA (defined as pre-total joint replacement, an indicator of joint failure). Exercise was the most commonly examined intervention of the 23 studies in the review, and the exercise programs included land- and water-based endurance, strengthening, and flexibility activities. Overall, there was low to moderate quality evidence of pain reduction prior to joint replacement with exercise intervention; the SMD was 0.43 for knee OA (95% CI, 0.13–0.73) and 0.52 (95% CI, 0.04–1.01) for hip OA. The pain reduction results for the knee are similar to a meta-analysis of 32 studies of mild and moderate knee OA (SMD, 0.40; 95% CI, 0.30–0.50).[22] Moderate-quality evidence of improved physical function with exercise programs was available for severe hip OA (SMD, 0.47; 95% CI, 0.11–0.83), but this effect was not observed for severe knee OA. The studies in this meta-analysis were mostly small RCTs (N = 1461, across all studies), and larger, well-designed RCTs are needed to provide clearer evidence of the effectiveness of exercise programs for severe OA.

Cost-Effectiveness of Exercise Programs for OA

Two recent reports have examined the cost-effectiveness of exercise programs for OA. In a meta-analysis of 11 studies by Pinto et al[91] examining conservative treatments (ie, exercise programs, acupuncture, rehabilitation programs, and lifestyle interventions), 3 studies that included supervised exercise interventions reported improved health outcomes (eg, better physical function or reduced pain) at a lower cost relative to home-based exercise alone,[92,93] usual care,[65] or 3 sessions of health education.[94] The programs examined a range of

exercises in these studies: 1) a physiotherapist-led class-based program of stretching, balance training, and strengthening for patients with knee OA[92,93]; 2) a water-based year-long program of strengthening, balance, and aerobic activity for people with hip and knee OA[65]; and 3) 2 programs of aerobic walking exercise and full body resistance training for individuals with knee OA.[94] In the large strength training program RCT of adults with chronic knee pain/OA previously described by Hurley et al,[25] the probability of cost-effectiveness was high (81%–100%) in the exercise/self-management group compared with the usual care group at 30-month follow-up. Probability of cost-effectiveness was based on an acceptability curve of willingness-to-pay a 1% increase in the proportion improving on the WOMAC function subscale by at least 15%. The results of these studies suggest that exercise programs for knee and hip OA not only improve outcomes but are also a cost-effective treatment approach.

Dissemination and Implementation of Exercise Programs for OA

Although there is strong evidence that exercise improves outcomes for patients with hip and knee OA, many individuals with OA are physically inactive. For example, in a cohort of individuals with radiographic knee OA, only 10% were currently meeting Department of Health and Human Services physical activity guidelines.[95] There is still a need for more research to increase understanding of the most effective formats and types of physical activity for patients with OA (and how this may vary according to individual patient characteristics), but there is also a critical need to move our current evidence base into practice. Accordingly, promotion of physical activity is a core component of the 2010 National Public Health Agenda for Osteoarthritis.[7] Research is needed to identify effective strategies for implementing evidence-based physical activity programs and fostering adoption and maintenance of physical activity among adults with OA.

SUMMARY

Evidence supports both aerobic exercise (land-based or water-based) and progressive strengthening exercise for reducing pain and improving physical function in patients with mild to moderate knee OA. Effects are generally comparable with estimates reported for simple analgesics and NSAIDs for the treatment of knee pain. Because of this strong evidence, clinicians should strongly encourage regular exercise for patients with knee OA.

Although the evidence base regarding exercise for patients with hip OA is much smaller than for knee OA, studies to date support the effectiveness for these patients. Because of the other important benefits of exercise for overall health, clinicians also should encourage exercise in these patients, even as data continue to emerge.

In addition to more traditional forms of exercise, a small but growing evidence base supports the effectiveness of other types of exercise (eg, Tai Chi, balance training, proprioceptive training) for patients with OA. Even though less is known about the effects of these types of exercise, they provide choices for patients with OA who want alternate forms of activity or to vary their exercise routine.

Many areas still are in need of further research regarding exercise for patients with OA. As previously noted, studies of exercise for patients with hip OA are very limited. Exercise based on biomechanical considerations of the hip should be examined because they may be appropriate and effective for patients with OA at this joint. Hip strengthening exercise programs seem promising but should be further evaluated to determine their effectiveness for the management of knee OA.

Few studies of exercise for patients with OA examine other joint sites, including the foot, ankle, and back. Studies of exercise for OA have evaluated relatively short-term outcomes, but the long-term benefits and potential effects on progression have not been well-established. Little is known about best methods for helping patients with OA to maintain exercise beyond a relatively limited study period.

Most studies have focused on patients with mild to moderate OA. A few reports suggest that adults with severe knee OA (pre-joint replacement) may exhibit improved function and reduced pain after exercise intervention, but larger, high-quality RCTs are necessary to confirm these initial findings. More information is needed on best strategies to foster exercise among patients with severe symptoms. Studies in this area would make an important contribution to clinical practice.

Optimal methods for supporting physical activity for patients with OA are not known. Some evidence suggests exercise programs that include direct supervision of ≥ 12 visits have an advantage for patients with knee OA. However, when this level of supervision is not possible, other key strategies may exist for supporting adoption and maintenance of exercise.

Participants in the exercise programs were generally older adults with a greater proportion of women, and comparisons of the effectiveness of program by factors of age and gender were not reported. Several studies conducted programs that allowed for exercise progression based on one's ability, which is a good treatment strategy, but examining effectiveness of programs by age, gender, or other factors (eg, obesity, as examined by Lim et al[75]) may inform tailored clinical care approaches.

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Table 1

Systematic Reviews of Exercise as a Treatment for Osteoarthritis

Study	Study Purpose	Design and Procedures	Number of Studies Reviewed	Number of Participants	Types of Intervention and Duration	Study Results and Conclusions
Mixed Land-Based Exercise Programs						
Fransen et al,[21]	To determine whether land-based exercise reduces joint pain or improved function in people with hip OA when compared with no exercise.	Meta-analysis; systematic review of 5 electronic databases from 1966–2008. All RCTs recruited people with hip OA and land-based therapeutic exercise groups were compared with nonexercise groups.	5 RCTs, but only 1 exclusively recruited people with hip OA. The other 4 RCTs also recruited participants with knee OA.	204 with hip OA for pain outcomes; 187 with hip OA for physical function outcomes.	Interventions were 6–12 wks. Class-based exercise interventions included strengthening, Tai Chi, and resistance. Classes were conducted 1–3 times per week.	Small improvement in pain (SMD, 0.38; 95% CI: 0.09–0.67). No change in self-reported function (SMD, 0.02; 95% CI, −0.31 to 0.28). Important limitations were the small number of studies with the small sample for this area of research.
Fransen& McConnell, [23]	To determine whether land-based exercise reduces joint pain or improved function in people with knee OA when compared with no exercise.	Meta-analysis; systematic review of 5 electronic databases up until December 2007	32 RCTs	3616 subjects with knee pain data and 3719 subjects with self-reported physical function data.	Programs were either delivered individually or in a class-based format, and most were home programs. Programs ranged from straight leg raises and mostly aerobic walking to very complex, comprehensive programs (manual therapy, strengthening, balance training and Tai Chi). Study duration ranged from 6–72 wks with sessions occurring 2–4 times per week.	Land-based exercise programs were beneficial (SMD, 0.40; 95% CI, 0.30–0.50; SMD, 0.37; 95% CI, 0.25–0.49) for physical function. Providing a greater number of directly supervised sessions (≥ 12 visits) improved knee pain and physical function outcomes.
Roddy et al[24]	To compare aerobic walking and home-based quadriceps strengthening exercises in patients with knee OA.	Meta-analysis of 5 electronic databases and the Cochrane Central Register of Controlled Trials (searched 1966–2003) for RCTs of subjects with knee OA.	13 RCTs total. 3 studies included an aerobic intervention, 9 studies included home-based strengthening exercises, and 1 aerobic walking with home-based strengthening program.	156 subjects from aerobic studies and 1709 subjects from strength training trials	Interventions were 8–24 weeks for aerobic walking and 8 wks–2 yrs for strengthening.	Pooled ES for pain: 0.52 for aerobic walking (95% CI, 0.34–0.70) and 0.32 for strengthening (95% CI, 0.23–0.41). Pooled ES for disability: 0.46 for aerobic walking (95% CI, 0.25–0.67) and 0.32 for strengthening (95% CI, 0.23–0.41). Both aerobic walking and home-based quadriceps strengthening exercises are effective in reducing pain and disability in knee OA.
Strength Training Programs						

Study	Study Purpose	Design and Procedures	Number of Studies Reviewed	Number of Participants	Types of Intervention and Duration	Study Results and Conclusions
Liu and Latham,[29]	To assess the effectiveness of PRT in older people.	Systematic review searching 8 electronic databases (1966–2008) plus reference lists of articles. Conference abstracts were reviewed and authors were contacted.	RCTs reporting physical outcomes of PRT for older people. 121 trials were identified, and 6 had participants with knee or hip OA.	503 participants with knee or hip OA	PRT was performed 2–3 times per week and at a high intensity.	Participants with OA reported a reduction in pain following PRT (SMD,−0.30; 95% CI, −0.487 to −0.13).
Latham & Liu,[30]	To determine the effectiveness of PRT in older adults with OA	Meta-analysis with systematic review of 9 databases.	8 RCTs. 7 trials of patients (mean age, 65) with knee OA and 1 trial included patients with hip and knee OA.	907 participants with 20–295 people in each study.	Moderate- to high-intensity programs that include 1–9 exercises. In 7 studies, participants exercised 3 times per week; 1 study had participants exercise 5 times per week. Duration of the programs ranged from 6–72 wks.	Reduced pain (SMD, −0.35; 95% CI, −0.52 to−0.18), improved function (SMD 0.33, 95% CI 0.18, 0.49), and improved leg extensor strength (SMD, 0.33; 95% CI 0.12–0.54) for PRT compared with nonstrength training control groups.
Pelland et al[38]	To determine the effectiveness of PRT programs in adults with OA.	Meta-analysis; a systematic review of 3 databases up to and including 2004; included RCTs of strengthening exercises and participants with OA.	21 trials	2325 patients with a primary diagnosis of OA.	Exercise types: isometric, isotonic, isokinetic, concentric, concentric/ eccentric, dynamic; alone or with other exercises (stretching, ROM); facility-based, home-based or both.	Strengthening exercises improved pain, range of motion, strength, and functional status in patients with OA. The combination of joint-specific strengthening with general strength and progression of the program were key components.
Balance and Neuromuscular Training						
Silva et a1[46]	To examine the effectiveness of exercise on the balance in women with OA.	Systematic review; 6 electronic databases and the Cochrane Collaboration RCTs published 2000–2010.	9 RCTs	833 participants	Exercise programs included: aerobic exercise and strength training, Tai Chi, hydrotherapy, vibrating platform exercise, balance exercises, and educational programs.	Interventions were 4 wks to 18 mo and a wide range of pain and balance assessments were used. Overall, balance of women with knee OA improved following exercise.
Smith et al[59]	To determine the effectiveness of proprioceptive exercises for knee OA.	Meta-analysis; systematic review of 7 published and 4 unpublished trial/registry (n=4) databases.	7 RCTs comparing a proprioceptive exercise program with a nonproprioceptive exercise program or nontreatment control for adults with OA.	560 patients with mean age of 63; 203 males and 357 females.	All proprioceptive exercises were weight-bearing, based on functional activities (ie, stepping, standing, walking, or balancing). Nonproprioceptive exercise programs were lower	Proprioceptive exercises significantly improved functional outcomes compared with nontreatment ($P < 0.02$). Outcomes were similar between proprioceptive and nonproprioceptive programs

Study	Study Purpose	Design and Procedures	Number of Studies Reviewed	Number of Participants	Types of Intervention and Duration	Study Results and Conclusions
					extremity exercises. Duration of the programs were 4–8 wks in duration.	the programs were 4–8 wks in duration.
					extremity exercises. Duration of the programs was 4–8 wks in duration.	the programs was 4–8 wks in duration.
					extremity exercises. Duration of the programs were 4–8 wks in duration.	the programs were 4–8 wks in duration.
					extremity exercises. Duration of the programs was 4–8 wks in duration.	the programs was 4–8 wks in duration. over uneven ground [$P = 0.03$] and joint position angulation error [$P < 0.01$].
Water-Based Programs						
Bartels et al[64]	To compare the effectiveness and safety of aquatic-exercise interventions in knee and hip OA.	Meta-analysis; 5 electronic databases were searched (1945–2006).	6 RCTs were identified, 4 included patients with hip or knee OA (N=672), 1 had subjects with hip OA only (N=28), and 1 had subjects with knee OA only (N=43).	800 participants	All types of exercises in therapeutic or heated indoor pool (range of motion, dynamics, aerobics, etc.) were included.	Small-to-moderate effect on function (SMD, 0.26; 95% CI, 0.11–0.42) and a small-to-moderate effect on quality of life (SMD, 0.32; 95% CI, 0.03–0.61).
Batterham et al[72]	To examine the effectiveness of aquatic compared with land-based exercise on function in people with arthritis.	Systematic review of 4 databases with meta-analysis.	10 RCTs compared land with aquatic exercise for adults with rheumatoid or OA. Land-based exercise could include any exercise training for strength, endurance, resistance, or aerobic capacity, whether gym or home-based.	354 water-based participants, 305 land-based participants, and 113 controls.	7 of the RCTs described the exercises in their land-based and aquatic programs. Duration was 4–18 wks. Aquatic exercise included running, jumping, cycling and walking, and strengthening exercises (ie, hip and knee flexion and extension, hip adduction and abduction, calf raises, and squats).	Results did not differ for the 2 rehabilitation strategies. The authors suggested that when people have difficulty with land based exercises, aquatic programs may be a good alternative.
Mixed Water-Based and Land-Based Programs (land-based, aquatic, and mixed)						
Escalante et al[76]	To examine the effectiveness and structure of exercise programs on pain in patients with hip and knee OA.	Systematic review of 5 electronic databases.	33 studies total with 22 land-based intervention studies (ie, strengthening, Tai Chi, aerobic), 5 aquatic studies, and 6 mixed exercise programs.	1507 subjects from land-based studies; 569 from aquatic studies, and 603 from mixed exercise program subjects	Study intervention duration lasted 6–72 wks (most often 8 wks) with 1–7 sessions/wk (most with 3 sessions/wk). 30–60 min sessions, with most at 30 min.	Pain decreased in 80% of strength interventions (ES, 0.01–1.12), 70% of Tai Chi studies (ES, 0.28–1.67), and 80% of the aquatic studies (ES, 0.19–0.72). Pain decreased in 1 of 2 aerobic studies (ES=1.06). Only 1 of the 6 mixed programs resulted in reduced pain (ES=0.40).
Escalante et al[77]	To examine the effectiveness and structure of exercise programs on functional aerobic capacity in	Systematic review of 7 databases.	20 studies; included 19 RCTs and 1 controlled clinical trial.	Total of 2142 subjects: the 19 RCTs included 2093 subjects; controlled clinical	Interventions included aerobic programs (n=4), strength programs (n=2), Tai Chi programs (n=3) mixed programs (n=8), and hydrotherapy programs	Functional aerobic capacity improved in Tai Chi program (ES = 0.66; 95% CI, 0.23–1.09), aerobic programs (ES = 0.90; 95% CI, 0.70–1.10), and mixed programs (ES = 0.47, 95% CI, –

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	individuals with hip and knee OA. individuals with hip and knee OA.			trial included 49 subjects.	(n=3). The outcome measure used was the 6-minute walk test.	0.38 to 0.39). Hydrotherapy programs did not improve functional aerobic capacity (ES 0.00; 95% CI,–0.38 to 0.39).

Abbreviations: ES, effect size; OA, osteoarthritis; PRT, progressive resistive training; RCT, randomized controlled trial; SMD, standardized mean difference.