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Resistance Exercise for Knee Osteoarthritis

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Abstract

The initiation, progression, and severity of knee osteoarthritis (OA) has been associated with decreased muscular strength and alterations in joint biomechanics. Chronic OA pain may lead to anxiety, depression, fear of movement, and poor psychological outlook. The fear of movement may prevent participation in exercise and social events which could lead to further physical and social isolation. Resistance exercise (RX) has been shown to be an effective intervention both for decreasing pain and for improving physical function and self-efficacy. RX may restore muscle strength and joint mechanics while improving physical function. RX may also normalize muscle firing patterns and joint biomechanics leading to reductions in joint pain and cartilage degradation. These physical adaptations could lead to improved self-efficacy and decreased anxiety and depression. RX can be prescribed and performed by patients across the OA severity spectrum. When designing and implementing an RX program for a patient with knee OA, it is important to consider both the degree of OA severity as well as the level of pain. RX, either in the home or at a fitness facility, is an important component of a comprehensive regimen designed to offset the physical and psychological limitations associated with knee OA. Unique considerations for this population include: 1) monitoring pain during and after exercise, 2) providing days of rest when disease flares occur, and 3) infusing variety into the exercise regimen to encourage adherence.

Keywords

knee; osteoarthritis; resistance exercise; pain; physical function

Introduction

Knee osteoarthritis (OA) is characterized by pain, articular cartilage deterioration, joint space narrowing and reduced muscle strength. Approximately 60 million Americans have knee OA and this number will increase by 50% over the next decade.¹ Knee pain during movement due to OA is a strong predictor of an increased need for functional assistance,² and is the second leading cause of disability in the US.³ Approximately 10–30% of people diagnosed with OA have pain severe enough to limit function and cause disability, and this percentage is increasing.⁴ Loss of leg muscular strength is associated with increased pain and disability, as well as a more rapid progression of knee OA. Aberrant biomechanics and abnormal joint forces have also been identified as potential culprits underlying OA onset and

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progression^{5, 6} Some evidence indicates that abnormal motion at the knee often precedes degenerative changes⁷ with decreased tibiofemoral rotation as a mechanism contributing to the development of cartilage degradation. People with medial compartment knee OA demonstrate an internal rotation bias with decreased tibiofemoral rotation compared to their unaffected age matched counterparts^{7, 8}. Increased ligament stiffness, decreased muscle strength, and alterations in muscle activation patterns are associated with aging and can adversely affect joint kinematics. Suboptimal muscle activation patterns contribute to adverse alterations in joint kinematics during movement. Chronic kinematic alterations can cause degenerative changes in the cartilage, particularly in older adults whose cartilage may no longer have the ability to adapt to load bearing. This is a serious issue for the individual with knee OA, as activities such as squatting, stair climbing and kneeling may load the tibial-femoral cartilage surfaces in areas that cannot tolerate the load. Pain, perceived instability, and functional limitations are common downstream effects of this degenerative process. Over time, self-efficacy declines, quality of life deteriorates, and physical dependency and social isolation may ensue. Chronic OA pain may trigger anxiety and depression, which perpetuate the progressive physical and psychological decline associated with the disease.

While options exist to treat pain due to OA, few treatments can affect the above mentioned factors underlying OA. Muscle strengthening through resistance exercise (RX) increases physical function, decreases pain due to OA, and reduces self-reported disability.^{5, 9, 10} RX, defined here as the use of machines (i.e. machines using a weight stack or added weights allowing selection of a given resistance load) or free weights as the external load, may combat the multi-faceted etiology of OA. This article will synopsise the highest quality evidence of the effects of RX on OA, and provide clinical guidelines for the prescription and expected adaptations to RX in the knee OA population.

Resistance Exercise Programming

Components of a RX program include resistance load, repetitions, velocity of movement and frequency of sessions per week. A periodic increase in the resistance load for each exercise permits continued muscular adaptations over time. Strength is best improved with lifting heavier loads with fewer repetitions, whereas muscle endurance is optimized by lifting lighter weights with more repetitions. RX can be described in terms of workload (number of repetitions at a given weight). When exercise total workload is kept constant, high-intensity (~6 to 8 repetitions at 80% of 1RM) and low-intensity (~12 to 15 repetitions at 60% of 1RM) induce similar strength and health adaptations in older men and women.^{11–13} For knee OA, benefits can be obtained with leg exercises alone, or a combination of lower and upper body exercise for general strengthening. Basic components of the OA prescription should include seated leg presses (or a variation of a squats), leg extensions and leg curls (with ankle or wrist cuff weights to provide resistance). Inclusion of hip adduction and hip abduction and calf/toe presses can help with improving and maintaining appropriate knee mechanics.

Initiation of a resistance training program requires assessment of strength, total knee range of motion, knee pain throughout the range of motion, and the patient's access to exercise equipment. Studies commonly report exercise intensity as the percentage of 1RM at which the exercises are performed. The term "repetition maximum" (RM) refers to the maximal number of times a load can be lifted before fatigue using appropriate form and technique (a 1RM = the maximum load that can be lifted once with proper form). Monitoring intensity during an RX program can be achieved by monthly reassessment of the exercise 1RM and readjustment of the resistance to provide an appropriate stimulus, or by subjective ratings of muscle effort during the exercise (e.g., Borg's rating of relative perceived exertion scale).¹⁴ The 0–10 or 6–20 points relative perceived exertion (RPE) scales can effectively be used to

help guide the difficulty of exertion during RX for each exercise.¹⁵ Hoeger et al¹⁵ demonstrated that exercises performed at the same percent of 1RM did not correlate to the same level of perceived difficulty. This may indicate that using the RPE scale to monitor effort may allow for each exercise to be performed at a similar level of perceived difficulty.

The severity of knee pain symptoms at rest and during the 1RM testing will provide important information when developing the initial resistance loads. While the radiographic findings are typically used to stage OA, these data have poor correlation to subjective pain ratings and functional limitations. Pain and range of motion are therefore more useful indicators of how to initiate and advance a RX program. For example, patients with low to moderate pain (between a 1–5 on a 10 point scale) may be able to initially tolerate higher loads or repetitions compared with patients who report higher pain levels. A successful program will incorporate exercises to which the patient has access. If access to RX machines is limited or is cost prohibitive, a home based exercise program using dumbbells or weight cuffs can be substituted.

Resistance Exercise Evidence from Randomized Controlled Trials

Resistance can be applied through various methods (i.e. body weight, bands, free weights, machines) but for consistency of definition, this review will focus on randomized controlled trials (RCTs) that used weight machines or free weights (please see Table 1.).^{16–21} The most commonly utilized regimens involved exercise three days per week, with 2–3 sets per exercise at 8–15 repetitions per set. Resistance loads varied among studies from relatively high resistance (80% 1RM)¹⁹ to low resistance (10% 1RM).²⁰ The efficacy of RX on OA symptoms and disability was tested against a variety of other regimens including hydrotherapy (pool walking),¹⁸ aerobic exercise (moderate intensity treadmill),^{16, 22, 23} and range of motion exercises (45 minutes of general multi-joint stretching).²¹ Other studies compared RX to “sham” RX (minimal leg press and leg extension exercise)¹⁹, self-management programs, and even health educational control interventions.^{16, 17} The health education and self management programs provided attention, social interaction, and osteoarthritis education; with exposure to coping skills, promotion of the use adaptive strategies and decreased reliance on avoiding activities or allowing others to perform the tasks for them. Study samples ranged from 54–365 and were conducted in the United States, Australia and Europe.

Pain

Common OA outcomes in these studies were the Western Ontario McMaster Osteoarthritis Index WOMAC pain and function subscores, Likert pain scores, leg strength and functional assessments. Some data show that WOMAC pain scores were reduced with 2–9 months of progressive RX by 42–43% compared to 14–23% reported in control type groups.^{17, 20} Compared to the control group (who performed range of motion exercise), the RX group demonstrated preserved strength and decreased progression of joint space narrowing over a 30 month period.²¹ Pain was not different in either group post-intervention.²⁴ Evidence suggests that pain relief might be dependent in part on exercise intensity; three sets (8 repetitions/set) of RX performed at 60% 1RM reduced WOMAC pain scores more than ten sets (15 repetitions/set) performed at 10% 1RM.²⁵ In one study by Foley et al.¹⁸ 70 subjects completed 6 weeks of hydrotherapy or RX. The WOMAC pain scores did not change with either group. The discrepant findings may be in part due to the severity of OA in the patient group recruited,²⁶ or the baseline pain levels of the study groups. For example, 44% of the patients in one study were on a joint replacement surgery waiting list.²⁶ Given the prevalence of severe disease, it is unlikely that meaningful RX-induced changes in knee pain would be detected among three groups of 35 participants after six weeks of training. Mikesky et al. showed that no differences in pain ratings occurred between RX and control

groups after a 12 month program (supervised to home transition program); half of the participants did not even report pain at the study onset; so it is not surprising that a significant change in pain was not detected in this study.²¹

Functional and Strength Improvements

Functional change may be assessed using self-report instruments or objective functional tests. Disability questionnaires may ask objective questions of perceived ability, or have distinct activity subscales relating to ambulation, stair climbing, transfer activities, upper extremity tasks, basic activities of daily living, and complex activities of daily living. Objective functional tests used in these studies include: stair climb and descent times, picking up and carrying a 10 pound weight, and timed task of getting in and out of a simulated car. Longer tasks include the six minute walk and walking endurance on an aerobic treadmill test.

Improving walking ability is clinically important as it is related to maintenance of functional independence, as well as a lower risk of mortality and admission to a nursing home.²⁷ Studies have shown that RX can decrease walking time on level surfaces for 60 meters by 8–10%²⁵ and improve six minute walking distance by an average of 28–45%.²⁸ Other studies have shown increases in median walking speed from 0.97 to approximately 1.12 meters per second (~15% change)²⁶ and 11% increases in habitual gait speed with RX and Sham groups over a six month period.²⁹ These improvements in gait speed^{26, 29} are considered clinically relevant.³⁰ Other tasks such as times to perform climbing a flight of stairs and rising from a chair reflect the ability of the individual to transfer body weight. Stair climbing power has been shown to increase by 19%²⁸ and self-efficacy of climbing stairs significantly improves after RX.²³ Other data support that chair rise time decreases in similar ranges of 12–28%.^{25, 28} Hence, in persons with knee OA, these mobility tasks become easier and are performed more efficaciously after RX training.

Muscle strength of the knee flexors and extensors consistently increases with RX interventions.^{25, 26, 29} In a study that compared strength improvement with an RX intervention (leg press, leg extension) or a sham intervention (leg press, leg extension) Foroughi et al. found that both groups increased muscle strength in the knee flexors and extensors as well as the hip flexors and abductors with greater changes occurring in the RX group (25–49% strength improvement in the RX group versus 2–15% increase in the sham group).²⁹ Isokinetic knee torque can increase more following higher RX intensities (higher resistance loads, fewer repetitions) than low RX intensities (low resistance for high repetition number).²⁰ Dose-dependent improvements in isokinetic strength occurred with chair rise time, stair climb power and six minute walking distance post-training, with higher intensity exercise inducing the greatest change with no adverse safety issues. Specifically, walking time to complete a 12 meter walk on a spongy surface decreases by 42%–50% following low and high intensity RX and the time to complete a figure eight pattern with two 50 meter circles decreases by 38% to 45%.²⁵ An advantage of a high intensity program is decreased total work-out time which may improve adherence. Long term studies that are initially supervised and transition to home based programs show that knee extensor and flexor torque increased most during the initial 3–6 month phase and then muscle strength slowly declines over the following years after the transition occurred.³¹ These data support the concept that improvements in symptoms and function are directly related to exercise intensity and that higher intensity RX (if maintained over time) would sustain muscle strength and preserve functional abilities. Figure 1 summarizes a potential pathway by which RX improves OA symptoms and disability.

Can Leg Exercise Alone Improve Strength or OA Symptoms?

The question of whether focused knee extension and flexion RX can elicit a similar magnitude of OA symptom relief as a comprehensive RX program remains unclear due to limited evidence. However, a small study used isolated RX of the knee extensors and flexors to treat patients with knee OA.³² Supervised RX was performed once a week using machines, at the intensity of 50% of the maximum peak torque for three sets at 20 repetitions. This was supplemented with 30 daily isometric strengthening exercises of the quadricep and hamstring muscles. The symptomatic leg produced less maximal knee extensor and flexor torques compared with the asymptomatic leg at baseline. However, after three to six months of training, the improvements in torque values were significantly greater in the symptomatic leg (72.5% vs 46.9% extension, 63.6% vs. 31.0% flexion). While adherence was not reported for exercise after month six, the strength improvements were maintained for three years. Hence, even isolated knee extension and flexion exercise can induce large improvements in strength, particularly in the more painful knee joint. Unfortunately this study did not document changes in pain or functional ability.

Severe OA: A Role for Resistance Exercise?

Importantly, even persons with severe OA who are awaiting a joint replacement can participate in high intensity RX and experience satisfaction with treatment, without worsening knee pain or inducing adverse events.¹⁸ Exploratory studies also show that RX can positively increase the Knee Injury and Osteoarthritis Outcome Score (KOOS) in the domains of pain, symptoms, activities of daily living, and quality of life.³³ While RX may not induce the same magnitude of symptom reduction and functional improvement in severe knee OA compared with less severe disease, performing strengthening exercise still confers positive benefits. For example, prehabilitation with RX prior to knee replacement may enhance postoperative recovery and functional gains after the procedure and reduce muscle strength asymmetries between the surgical and non-surgical leg.³⁴ This is clinically relevant because preoperative functional status is predictive of postoperative performance on a variety of functional tasks, and preoperative quadriceps strength is a predictor of physical function (e.g., stair climb, chair rise) at one year after knee replacement.³⁵ These data provide compelling evidence that RX can be helpful even in end stage knee OA.

Psychological Importance of Resistance Exercise in Knee OA

Maintenance of positive psychological well being is critical in the prevention of worsening disability in the OA population. Benefits of RX extend beyond pain relief and functional improvement, and can include psychosocial well being. Psychological well-being typically encompasses positive components such as cognitive function, positive affect, enhanced self-efficacy and self-esteem with the absence of anxiety, depression, and negative stress-related emotions.³⁶

Self efficacy, Anxiety and Depression

Chronic OA pain may lead to anxiety, depressive symptoms and poor psychological outlook.^{37, 38} Self-efficacy beliefs are clinically important because the confidence that one can exercise, despite individual constraints and impediments such as lack of time and fatigue are associated with a greater likelihood of success with healthy behaviors. Patients with low self-efficacy are more likely to avoid physical activity in their daily routine.²³ Older adults who participate in whole body RX experience a sense of accomplishment and control over their health with the achievement of a new physical competency. Participants may accept responsibility for their health with the intent of preventing health problems later.³⁹ A sub-analysis from an exercise intervention RCT in knee OA revealed that RX can increase self-efficacy for stair climbing as much as aerobic exercise, and this is in part mediated by pain

reduction.²³ As self-efficacy decreases, trust in self to perform physical function declines. According to Maly, people with knee OA demonstrate a concept termed “careful mobility,”⁴⁰ represented by cautious behaviors such as slow walking velocity, increased stance time, reduced joint angles, and decreased range of motion.

Concurrent with strength gains, RX can reduce anxiety, improve mood and reduce the risk of depression in older adults when regimens involve resistance loads of 80% 1RM for two sets of eight repetitions of six exercises.³⁷ Even among depressed elders, RX confers a 46% reduction in Beck Depression Inventory scores compared to a 20% reduction in controls.³⁸ Quality of life subscores of role emotional, social functioning and bodily pain are all improved with RX.

Resistance Exercise Prescription for Knee OA

The prescription of RX for knee OA is provided in Table 2. Note that as the severity of the OA pain increases, modifications to the initial program and progression should be made for patient comfort and adherence. In general, the initiation phase of RX programs can involve strengthening exercise twice a week and work up to three times a week. The initial resistance loads and the range of motion of the exercises can be tailored to the patient tolerance. The goal should be to encourage training at an intensity to induce an RPE of 13–15 (“somewhat hard” to “hard”). The joint range of motion for the different leg exercises should be set as the maximum range that can be tolerated by the patient. During the progression stage the resistance loads or number of weekly sessions can be increased as the patient gains strength, confidence, and becomes skilled at rating muscle effort and interpreting knee pain during the exercise. A minimum of 24 hours rest between sessions should be implemented. Maintenance of strength gains and function over time can be achieved by performing leg exercises at an intensity that induces an RPE of 15–16. Variety in the exercise program can be infused with different leg exercises, performing unilateral versus bilateral exercise, or substituting free weight exercise such as squats with dumbbells, lunges, or step ups on to a stair or platform while holding light weights. Variety within the RX program fosters adherence and reduces stagnation. By following some guidelines for the relative RX activity (Table 3), injury risk is minimized in persons with knee OA.

In patients with severe pain (exceeding 7 out of 10), physicians should consider beginning with physical therapy and pharmaceutically controlling pain prior to adding greater resistance loads. An important point is that RX programs for OA need to be flexible to accommodate the disease flares and episodic pain bouts. Our experience revealed that minor modifications to the prescription (particularly to reducing resistance load and/or range of motion) on “bad days” permits the patient to continue exercising, improves adherence, and bolsters self-confidence that they can still accomplish an exercise session. Within a few days, the patient may be back at the designated training load and joint motion.

Translation of Principles into Medical Practice

Prescription of RX for the treatment of mild to moderate knee OA will provide multiple benefits including symptom relief, less disability, improved functional capacity and overall health. It is important to note that access to facilities that house resistance exercise equipment, or formal RX programs may be cost prohibitive. In such cases, home-based RX programs that use body weight, therabands, dumbbells and cuff weight may confer substantial benefit against adverse OA sequelae. For example, functional activities combined with strengthening exercise with weight cuffs (squats and step-ups, knee extension/flexion, hip abduction/adduction) performed three times a week can elicit 43% reductions in pain with concurrent improvements in leg strength, stair climb time and repeated chair stand time.⁴¹ Other home-based programs and telephone prompted programs

that use graded elastic bands for leg exercise can also significantly reduce OA pain symptoms compared to no exercise,^{42–44} and improve the ability perform body transfers with less pain.⁴³ Thus, an initial purchase of select inexpensive resistance exercise items, coupled with a booklet with 5–8 exercises or dynamic activities describing the technique, load and repetition structure with guidance of progression, is a suitable alternative for patients with knee OA.

Conclusion

RX exercise is a vital component of the treatment for some of the underlying mechanisms of knee OA, including muscle strength insufficiency, muscle activation imbalance and aberrant biomechanics and cartilage loading. RX can be modified based on the patient symptoms and access to equipment. Progression and maintenance of benefits can be safely achieved by following the guidelines presented here.

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References

1. Garstang SVST. Osteoarthritis: epidemiology, risk factors, and pathophysiology. *Am J Phys Med Rehabil.* 2006; 85(11):S2–11. [PubMed: 17079976]
2. Jinks C, Jordan K, Croft P. Osteoarthritis as a public health problem: the impact of developing knee pain on physical function in adults living in the community: (KNEST 3). *Rheumatology (Oxford).* 2007; 46(5):877–881. [PubMed: 17308312]
3. American Medical Association white paper on elderly health. Report of the Council on Scientific Affairs. *Arch Intern Med.* 1990; 150(12):2459–2472. [PubMed: 2288622]
4. Prevalence and impact of arthritis by race and ethnicity--United States, 1989–1991. *MMWR Morb Mortal Wkly Rep.* 1996; 45(18):373–378. [PubMed: 8606687]
5. Lange AK, Vanwanseele B, Fiatarone Singh MA. Strength training for treatment of osteoarthritis of the knee: a systematic review. *Arthritis Rheum.* 2008; 59(10):1488–1494. [PubMed: 18821647]
6. Liu CJ, Latham NK. Progressive resistance strength training for improving physical function in older adults. *Cochrane Database Syst Rev.* 2009; (3):CD002759. [PubMed: 19588334]
7. Andriacchi TP, Mundermann A, Smith RL, Alexander EJ, Dyrby CO, Koo S. A framework for the in vivo pathomechanics of osteoarthritis at the knee. *Ann Biomed Eng.* 2004; 32(3):447–457. [PubMed: 15095819]
8. Andriacchi TP, Koo S, Scanlan SF. Gait mechanics influence healthy cartilage morphology and osteoarthritis of the knee. *J Bone Joint Surg Am.* 2009; 91 (Suppl 1):95–101. [PubMed: 19182033]
9. Gur H, Cakin N, Akova B, Okay E, Kucukoglu S. Concentric versus combined concentric-eccentric isokinetic training: effects on functional capacity and symptoms in patients with osteoarthrosis of the knee. *Arch Phys Med Rehabil.* 2002; 83(3):308–316. [PubMed: 11887109]
10. Penninx BW, Messier SP, Rejeski WJ, et al. Physical exercise and the prevention of disability in activities of daily living in older persons with osteoarthritis. *Arch Intern Med.* 2001; 161(19):2309–2316. [PubMed: 11606146]
11. Vincent KR, Braith RW. Resistance exercise and bone turnover in elderly men and women. *Med Sci Sports Exerc.* 2002; 34(1):17–23. [PubMed: 11782642]
12. Vincent KR, Braith RW, Feldman RA, et al. Resistance exercise and physical performance in adults aged 60 to 83. *J Am Geriatr Soc.* 2002; 50(6):1100–1107. [PubMed: 12110072]
13. Vincent KR, Vincent HK, Braith RW, Lennon SL, Lowenthal DT. Resistance exercise training attenuates exercise-induced lipid peroxidation in the elderly. *Eur J Appl Physiol.* 2002; 87(4–5):416–423. [PubMed: 12172882]

14. Borg GAV. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc.* 1982; 14:377–381. [PubMed: 7154893]
15. Hoeger WK, Hopkins DR, Barette SL, Hale DF. Relationship between repetitions and selected percentages of one repetition maximum: a comparison between untrained and trained males and females. *J Appl Sport Sci Res.* 1990; 4(2):47–54.
16. Ettinger WHJ, Burns R, Messier SP, et al. A randomized trial comparing aerobic exercise and resistance exercise with a health education program in older adults with knee osteoarthritis. The Fitness Arthritis and Seniors Trial (FAST). *JAMA.* 1997; 277(1):25–31. [PubMed: 8980206]
17. Farr JN, Going SB, McKnight PE, Kastle S, Cussler EC, Cornett M. Progressive resistance training improves overall physical activity levels in patients with early osteoarthritis of the knee: a randomized controlled trial. *Phys Ther.* 2010; 90(3):356–366. [PubMed: 20056719]
18. Foley A, Halbert J, Hewitt T, Crotty M. Does hydrotherapy improve strength and physical function in patients with osteoarthritis--a randomised controlled trial comparing a gym based and a hydrotherapy based strengthening programme. *Ann Rheum Disord.* 2003; 62(12):1162–1167.
19. Foroughi N, Smith RM, Lange AK, Baker MK, Fiatarone Singh MA, BV. Progressive resistance training and dynamic alignment in osteoarthritis: A single-blind randomised controlled trial. *Clin Biomech (Bristol, Avon)*. 2011; 26(2):167–174.
20. Jan MH, Lin JJ, Liao JJ, Lin YF, Lin DH. Investigation of clinical effects of high- and low-resistance training for patients with knee osteoarthritis: a randomized controlled trial. *Phys Ther.* 2011; 88:427–436. [PubMed: 18218827]
21. Mikesky AE, Mazzuca SA, Brandt KD, Perkins SM, Damush T, Lane KA. Effects of strength training on the incidence and progression of knee osteoarthritis. *Arth Rheum.* 2006; 55(5):690–699. [PubMed: 17013851]
22. Penninx BW, Rejeski WJ, Pandya J, et al. Exercise and depressive symptoms: a comparison of aerobic and resistance exercise effects on emotional and physical function in older persons with high and low depressive symptomatology. *J Gerontol B Psychol Sci Soc Sci.* 2002; 57(2):P124–132. [PubMed: 11867660]
23. Rejeski WJ, Ettinger WH Jr, Martin K, Morgan T. Treating disability in knee osteoarthritis with exercise therapy: a central role for self-efficacy and pain. *Arth Care Res.* 1998; 11(2):94–101. [PubMed: 9668732]
24. Mikesky AE, Mazzuca SA, Brandt KD, Perkins SM, Damush T, Lane KA. Effects of strength training on the incidence and progression of knee osteoarthritis. *Arthritis Rheum.* 2006; 55(5): 690–699. [PubMed: 17013851]
25. Jan MH, Lin JJ, Liao JJ, Lin YF, Lin DH. Investigation of clinical effects of high- and low-resistance training for patients with knee osteoarthritis: a randomized controlled trial. *Phys Ther.* 2008; 88(4):427–436. [PubMed: 18218827]
26. Foley A, Halbert J, Hewitt T, Crotty M. Does hydrotherapy improve strength and physical function in patients with osteoarthritis--a randomised controlled trial comparing a gym based and a hydrotherapy based strengthening programme. *Ann Rheum Dis.* 2003; 62(12):1162–1167. [PubMed: 14644853]
27. Sharkey NA. The role of exercise in the prevention and treatment of osteoporosis and osteoarthritis. *Nurs Clin North Am.* 2000; 35:209–221. [PubMed: 10673576]
28. Seynnes O, Fiatarone Singh MA, Hue O, Pras P, Legros P, Bernard PL. Physiological and functional responses to low-moderate versus high-intensity progressive resistance training in frail elders. *J Gerontol A Biol Sci Med Sci.* 2004; 59(5):503–509. [PubMed: 15123761]
29. Foroughi N, Smith RM, Lange AK, Baker MK, Fiatarone Singh MA, Vanwanseele B. Lower limb muscle strengthening does not change frontal plane moments in women with knee osteoarthritis: A randomized controlled trial. *Clin Biomech (Bristol, Avon).* 2011; 26(2):167–174.
30. Angst F, Aeschlimann A, Michel BA, Stucki G. Minimal clinically important rehabilitation effects in patients with osteoarthritis of the lower extremities. *J Rheumatol.* 2002; 29(1):131–138. [PubMed: 11824949]
31. Iwamoto J, Takeda T, Sato Y. Effect of muscle strengthening exercises on the muscle strength in patients with osteoarthritis of the knee. *Knee.* 2007; 14(3):224–230. [PubMed: 17395467]

32. Iwamoto J, Takeda T, Sato Y. Effect of muscle strengthening exercises on muscle strength in patients with osteoarthritis of the knee. *The Knee*. 2007; 14:224–230. [PubMed: 17395467]
33. McQuade KJ, de Oliveira AS. Effects of progressive resistance strength training on knee biomechanics during single leg step-up in persons with mild knee osteoarthritis. *Clin Biomech (Bristol, Avon)*. 2011; 26(7):741–748.
34. Swank AM, Kachelman JB, Bibeau W, et al. Prehabilitation before total knee arthroplasty increases strength and function in older adults with severe osteoarthritis. *J Strength Cond Res*. 2011; 25(2):318–325. [PubMed: 21217530]
35. Mizner RL, Petterson SC, Stevens JE, Axe MJ, Snyder-Mackler L. Preoperative quadriceps strength predicts functional ability one year after total knee arthroplasty. *J Rheumatol*. 2005; 32(8):1533–1539. [PubMed: 16078331]
36. McAuley E, Elavsky S, Jerome GJ, Konopack JF, Marquez DX. Physical activity-related well-being in older adults: social cognitive influences. *Psychol Aging*. 2005; 20(2):295–302. [PubMed: 16029093]
37. Cassilhas RC, Antunes HK, Tufik S, de Mello MT. Mood, anxiety, and serum IGF-1 in elderly men given 24 weeks of high resistance exercise. *Percept Mot Skills*. 2010; 110(1):265–276.
38. Singh NA, Clements KM, Fiatarone MA. A randomized controlled trial of progressive resistance training in depressed elders. *J Gerontol A Biol Sci Med Sci*. 1997; 52(1):M27–35. [PubMed: 9008666]
39. Dionigi R. Resistance training and older adults' beliefs about psychological benefits: the importance of self-efficacy and social interaction. *J Sport Exerc Psychol*. 2007; 29(6):723–746. [PubMed: 18089901]
40. Maly MR. Linking biomechanics to mobility and disability in people with knee osteoarthritis. *Exerc Sci Sports Exerc*. 2009; 37(1):36–42.
41. Baker KR, Nelson ME, Felson DT, Layne JE, Sarno R, Roubenoff R. The efficacy of home based progressive strength training in older adults with knee osteoarthritis: a randomized controlled trial. *J Rheumatol*. 2001; 28(7):1655–1665. [PubMed: 11469475]
42. Thomas KS, Muir KR, Doherty M, Jones AC, O'Reilly SC, Bassey EJ. Home based exercise programme for knee pain and knee osteoarthritis: randomised controlled trial. *BMJ*. 2002; 325(7367):752. [PubMed: 12364304]
43. Topp R, Woolley S, Hornyak J 3rd, Khuder S, Kahaleh B. The effect of dynamic versus isometric resistance training on pain and functioning among adults with osteoarthritis of the knee. *Arch Phys Med Rehabil*. 2002; 83(9):1187–1195. [PubMed: 12235596]
44. O'Reilly SC, Muir KR, Doherty M. Effectiveness of home exercise on pain and disability from osteoarthritis of the knee: a randomised controlled trial. *Ann Rheum Dis*. 1999; 58(1):15–19. [PubMed: 10343535]
45. Foroughi N, Smith RM, Lange AK, Baker MK, Fiatarone Singh MA, Vanwanseele B. Lower limb muscle strengthening does not change frontal plane moments in women with knee osteoarthritis: A randomized controlled trial. *Clinical Biomechanics (Bristol, Avon)*. 2011; 26(2):167–174.

Resistance Exercise (RX) Intervention

Figure 1.

Summary of main effects of resistance exercise (RX) on key musculoskeletal mechanisms underlying knee OA.

Table 1

Randomized controlled trials (RCTs) of resistance exercise for knee OA.

	N	Program type	Intervention	Follow-up	Pain reduction	Functional Gain
Eitinger et al. ¹⁶	365	Group FAST study	Supervised to home exercise 3 days per week RX: 9 exercises with cuffs and dumbbells, 2 sets of 12 repetitions; 1 hr AX: walking 1 hr, 50–75% HRR <u>Health education control</u>	18 months	Likert pain scale ranging from 0="no pain" to a max of 6="excruciating pain." Pain ↓ to 2.14, 2.21 and 2.41 points in the AX, RX and controls	Self report disability ↓ in both RX and AX groups; 6 minute walk, transfers, lift and carry and car tasks; knee flexion strength ↑; greater benefits occurred with greater compliance.
Farr et al. ¹⁷	171	Group	Supervised 3 days per week RX: leg press, leg curl, hip adduction/abduction, calf raise; progressive ↑ in load up to 60–75% of 3RM <u>Self-management (SM):</u> Educational and behavioral techniques; exercise guidelines provided <u>RX + Self management: both</u>	9 months	WOMAC 42% ↓ in RX group 31% ↓ in combined group 23% ↓ in SM	Average daily moderate/vigorous physical activity ↑ in RX more than SM group; RX group had highest strength gain in all exercises than other groups.
Foley et al. ¹⁸	105	Individual	Supervised 3 days per week <u>Hydrotherapy:</u> pool walking and leg strengthening; up to 3 sets of 15 reps per exercise RX: bench press, leg press, Hip adduction/abduction; 10RM intensity <u>Control: no exercise</u>	6 weeks	WOMAC Pain scores ↓ more in hydrotherapy during the study, but there was no difference in scores between exercise groups at week 6	Walking speed and isometric quadricep strength ↑ most in RX group; walk distance was greater at six weeks in hydrotherapy group.
Foroughi et al. ⁴⁵	54	Individual	Supervised 3 days per week RX: leg press, unilateral knee extension, hip abduction, hip adduction, plantar flexion; 80% 1RM progress 3% if RPE fell below range of 15–18 points 3 sets of 8 repetitions <u>Sham:</u> leg press, leg extension 2 sets of 8 repetitions	6 months	WOMAC pain scores ↓ in both groups 21–32% (p>0.05)	Greater ↑ in strength occurred in the RX vs Sham group for all exercises; WOMAC function in both groups by 21–31% in both Sham and RX groups, respectively, no difference between groups by month 6.
Jan et al. ²⁰	102	Individual	Supervised 3 days per week <u>HighR RX:</u> 60% 1RM, 3 sets 8 repetitions per set <u>LowR RX:</u> 10% 1RM, 10 sets 15 repetitions per set Progression 5% ↑ load as Tolerated <u>Control: no exercise</u>	2 months	WOMAC 43% ↓ in HighR RX 38% ↓ in LowR RX 14% ↓ in control	Walking time on 4 different terrains (level 60m, figure 8, 13 step stair climb, spongy surface) improved in both RX groups; WOMAC function ↓ 11.3–11.7% in the LowR and High R RX groups. Isokinetic knee extensor/flexor torque improved most in the HighR RX group.
Mikesky et al. ²¹	221	Individual	Supervised to home exercise RX: 3 days per week, transition sessions to home; Cybex leg press, leg curl, chest press, seated rows; 3 sets of 8–10 repetitions Progression occurred when 12 Repetitions were achieved <u>Range of Motion (ROM) control:</u> Flexibility exercises	30 months	WOMAC RX did not change pain scores during the study	WOMAC function tended to be better preserved by RX than ROM by month 30; isotonic quadricep and hamstring strength ↑ more in men than women by month 30.
Pennix et al.	438	Group FAST study	Supervised to home exercise 18 months 3 month facility and 15 months home exercise RX: 9 dumbbell exercises AX: walking 1 hr at 50–75% HHR <u>Control: monthly education</u>	Knee pain scale Pain scores ↓ in both RX and AX groups	When accounting for knee pain and disability, RX and AX both ↑ walking speed and ↓ pain, with the greater effect from AX by month 18.	

N	Program type	Intervention	Follow-up	Pain reduction	Functional Gain
Rejeski et al. ²³	357 Group FAST study	Supervised to home exercise 18 months 3 month facility and 15 months home exercise RX: 9 dumbbell exercises AX: walking 1 hr at 50–75% HHR Control: monthly education	compared with control Knee pain scale Pain scores ↓ in both RX and AX groups compared with control	Stair climb time ↓ with RX and efficacy ↑ in both the AX and RX groups. Pain severity and self-efficacy mediated the effect of exercise on stair climb performance irrespective of exercise type.	

RX = resistance exercise; AX = aerobic exercise; WOMAC = Western Ontario McMaster Osteoarthritis Index; RPE = rating of perceived exertion; HighR = high intensity resistance; LowR = low intensity resistance; FAST = Fitness, Arthritis and Seniors Trial; HHR = heart rate reserve

Table 2

Resistance exercise (RX) guidelines and prescription for individuals with knee OA.

Severity of Knee Pain	Mild (1–4 points out of 10)	Moderate (5–7 points out of 10)	Severe (>7 points out of 10)
INITIATION	2 days a week 40% 1RM RPE 13–15 Encourage full knee ROM Ice and manage pain as needed	2 days a week 40% 1RM RPE 13–15 Encourage full knee ROM or ROM as tolerated Take day off if flare is bad Manage pain as needed	2 days a week 30% 1RM RPE 13 ROM as tolerated Take day off if flare is bad Ice and manage pain as needed
Notes:			
PROGRESSION	Increase RPE up to 15–16 over 8 weeks Increase frequency up to 3 days a week, at least 24 hrs between sessions	Increase RPE up to 15–16 over 8 weeks Increase frequency up to 3 days a week, at least 24 hrs between sessions	Increase RPE as tolerated or up to 15 2 days per week, if tolerated, potentially up to 3 sessions per week; at least 24 hrs between sessions
MAINTENANCE	Maintain 2–3 days per week Adjust resistance load to keep RPE at 15–16	Maintain 2–3 days per week Adjust resistance load to keep RPE at 15–16	Maintain 2–3 days per week Adjust resistance load to keep RPE 15

(ROM = range of motion; RPE = rating of perceived exertion)

Table 3

Relative RX activity guidelines for knee OA

RX Progression:

- Only change one variable of the program at a time (repetitions, resistance, frequency).
- Keep RPE in the recommended range and do not increase training volume by more than 5% per week.
- Ceiling Effect: The participant may find a training level at which the pain symptoms increase. This is the ceiling at which the volume should not be increased. At this time, other exercises can be mixed in to the program or substituted to provide a novel stimulus to the muscle group (e.g., substitute a lunge exercise periodically with a leg extension machine exercise).
- Do not perform RX for the same muscle group on consecutive days.

Pain and Exercise:

- No more than mild discomfort (0–3/10 point scale).
- If the participant feels moderate pain (4–6/10): recommend reducing the RX activity until pain level is mild.
- Pain that decreases with activity is generally **OK**; discontinue the exercise or reduce the intensity if pain progressively worsens during the exercise.
- Pain should not carry over to the next day – the “24 hour Pain Rule”. If pain is worsened by 24 hours after the RX session, allow the pain to subside and lower the resistance on the next RX session.
- No limping allowed: If the exercise induced pain alters the participant’s gait pattern, the activity was performed too intensely or incorrectly. Avoid the activity until it can be performed with normal biomechanics.

From Vincent KR et al. “RX Activity Guidelines for Knee OA”