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Review

A review of the clinical evidence for exercise in osteoarthritis of the hip and knee☆

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Abstract

Osteoarthritis (OA) is a chronic joint disease with the hip and knee being commonly affected lower limb sites. Osteoarthritis causes pain, stiffness, swelling, joint instability and muscle weakness, all of which can lead to impaired physical function and reduced quality of life. This review of evidence provides recommendations for exercise prescription in those with hip or knee OA. A narrative review was performed. Conservative non-pharmacological strategies, particularly exercise, are recommended by all clinical guidelines for the management of OA and meta-analyses support these exercise recommendations. Aerobic, strengthening, aquatic and Tai chi exercise are beneficial for improving pain and function in people with OA with benefits seen across the range of disease severities. The optimal exercise dosage is yet to be determined and an individualized approach to exercise prescription is required based on an assessment of impairments, patient preference, co-morbidities and accessibility. Maximising adherence is a key element dictating success of exercise therapy. This can be enhanced by the use of supervised exercise sessions (possibly in class format) in the initial exercise period followed by home exercises. Bringing patients back for intermittent consultations with the exercise practitioner, or attendance at "refresher" group exercise classes may also assist long-term adherence and improved patient outcomes. Few studies have evaluated the effects of exercise on structural disease progression and there is currently no evidence to show that exercise can be disease modifying. Exercise plays an important role in managing symptoms in those with hip and knee OA.

Keywords: Osteoarthritis knee; Knee joint; Hip joint exercise; Knee; Muscle stretching exercises; Resistance training; Rehabilitation

Contents

1. Background

This paper provides an overview of appropriate exercise intervention for the special needs of people with osteoarthritis (OA) of the hip or knee. It is beyond the scope of this paper to discuss exercise prescription for the prevention of OA or following joint replacement surgery. Instead, it will

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focus on exercise for the management of symptoms in those with established hip and knee OA and briefly mention the limited research into the effects of exercise on structural disease progression.

Osteoarthritis is a chronic localized joint disease and a leading cause of musculoskeletal pain and disability. In 2007, 7.8% of Australians had OA[1] and this is projected to increase to 11% by 2050 due to population ageing and rising obesity rates. The knees, followed by the hips, are the most commonly affected weight-bearing joints.

The OA disease process involves the whole joint including cartilage, bone, ligament and muscle with changes such as joint space narrowing, bony osteophytes and sclerosis seen on X-ray. Risk factors are multifactorial and include older age, female gender, obesity (particularly in knee OA), previous joint injury, genetics and muscle weakness. Pain is the dominant symptom although it is important to note that the severity of pain and the extent of changes on X-ray are not well correlated. Pain together with joint stiffness, instability, swelling and muscle weakness leads to physical and psychological disability and impaired quality of life. Individuals with hip or knee OA have difficulty with activities of daily living, such as walking, stair-climbing and housekeeping. Furthermore people with OA commonly have a number of co-existing obesity-related disorders such as heart disease, hypertension and diabetes[2] and the majority of people with OA do not achieve recommended levels of moderate physical activity.[3]

There is currently no cure for OA and treatment options may be non-pharmacological, pharmacological or surgical. Total knee or hip joint replacement is common for advanced disease. Clinical guidelines advocate conservative non-pharmacological strategies, including exercise, given their ease of application, small number of potential adverse effects, and relatively low costs.[4,5]

2. Role of exercise in treatment of hip and knee osteoarthritis

Given the large body of evidence demonstrating the beneficial clinical effects of exercise in people with lower limb OA varying in severity from mild to severe, exercise therapy is regarded as the corner-stone of conservative management for the disease.[3–5] The main goals of exercise in this patient group are to reduce pain, improve physical function and optimize participation in social, domestic, occupational and recreational pursuits [5]. Regular exercise can improve physiological impairments associated with OA including muscle strength, joint range of motion, proprioception, balance and cardiovascular fitness.[6–9] Other potential benefits of exercise for this patient group include improvements in mobility, falls risk, body weight, psychological state and metabolic abnormalities. Exercise therapy for people with lower limb OA may take many forms however given the significant impact of muscle weakness on pain and function in OA,[10] muscle strengthening is a key component of most exercise regimes for knee and hip OA.

Land-based exercise has been consistently shown to reduce knee pain and improve physical function in people with knee OA.[11] A recent Cochrane Review identified 32 clinical trials investigating land-based therapeutic exercise for knee OA.[12] A wide range of therapeutic exercise programs were assessed, including those delivered individually to the patient, class-based programs and exercises designed to be undertaken by the patient at home. Treatment content varied from the relatively simple (e.g. quadriceps muscle strengthening, aerobic walking programs) through to very complex (e.g. including manual therapy, upper limb and/or truncal muscle strengthening and balance coordination in addition to lower limb muscle strengthening). A meta-analysis showed moderate treatment benefits with effect sizes of 0.40 (95% CI 0.30–0.50) for pain and 0.37 (95% CI 0.25–0.49) for physical function.[12] These effect sizes are similar to those effects achieved from simple analgesia and non-steroidal anti-inflammatory drugs but with much fewer side effects.[11]

Systematic reviews have evaluated specifically the efficacy of strengthening[13,14] and aerobic exercise[13] in people with OA at any joint (but predominantly knee). Clinical trials of strengthening exercise have spanned isometric, isotonic, isokinetic, concentric, concentric/eccentric and dynamic modalities. Strengthening improves strength, pain and physical function although the effects on quality of life and depression are yet to be confirmed. There appears to be no evidence that the type of strengthening exercise influences outcome.[13] Regarding aerobic exercise, 12 trials were identified.[13] Results indicated that aerobic exercise benefits pain, joint tenderness, functional status and respiratory capacity.

In contrast to knee OA, there is much less research into the role of exercise in hip OA. A recent Cochrane Review of land-based exercise for hip OA could only identify five clinical trials for inclusion.[15] The authors demonstrated a small treatment effect for pain, but no benefit regarding self-reported physical function. These findings are consistent with those of another recent systematic review where the authors concluded that there was insufficient evidence to suggest that exercise therapy alone can be an effective short-term management approach for reducing pain levels and improving function, and quality of life in people with hip OA.[16] These reviews conflict with another meta-analysis that included water-based programs to evaluate the efficacy of all types of exercise for hip OA.[17] The review concluded that therapeutic exercise, especially that incorporating specialized supervised exercise training and an element of strengthening, is an efficacious treatment for hip OA.

Although hydrotherapy is frequently advocated for patients with OA, relatively little robust research has been conducted in this area compared to land-based exercise. A Cochrane Review evaluating the effectiveness and safety of aquatic-exercise interventions for knee and hip OA identified only six trials for inclusion.[18] When all patients with knee

and hip OA were combined, there was a small-to-moderate effect on function and a small-to-moderate effect on quality of life. No effect of aquatic exercise was observed regarding walking ability or joint range of motion. Aquatic exercise is an option for exercise prescription in patients with OA but access to appropriate facilities and patient willingness to undertake water exercise need to be considered.

Tai Chi is a popular exercise intervention in older people especially those with OA due to its use of slow gentle movement, weight shifting, functional strengthening in weight-bearing postures and deep regulated breathing techniques. Studies show that Tai Chi is beneficial for pain, function, balance, flexibility and aerobic capacity in patients with chronic conditions including OA[19,20] although the methodological quality of research is generally less than that of studies of strength and aerobic training.

A limited number of clinical trials have directly evaluated the effect of exercise on structural disease progression in people with established OA, all at the knee[4,21,22] and with only one study including disease progression as the primary outcome.[22] In this 30-month clinical trial, strength training with an emphasis on quadriceps and hamstrings strengthening was compared to range of motion exercises as a control. There was no significant difference in X-ray changes between the groups. Other clinical trials have also failed to find reductions in the knee adduction moment, a measure of knee load and a predictor of structural disease progression,[23] with quadriceps[24] and hip abductor[25] strengthening in people with knee OA. Thus, while exercise can reduce symptoms, there is currently no evidence to suggest that exercise can also influence structural disease and thus be disease modifying.

3. Exercise prescription – boundaries of evidence

There are a number of areas where evidence is limited or research has not been undertaken. Relative to knee OA, there is far less research on exercise for hip OA and findings from studies involving patients with knee OA cannot necessarily be directly extrapolated to the hip given differences in biomechanics, impairments, rapidity of progression and risk factors. Therefore, while current international treatment guidelines recommend therapeutic exercise for people with symptomatic hip OA,[26,27] these recommendations are based largely on expert opinion. From a clinical perspective, the optimal exercise modality and dosage for OA is currently not known, as very few studies have compared regimes on the basis of exercise modality, intensity, duration and/or frequency. In clinical practice, exercise is often delivered in combination with other treatment modalities (such as drugs or physiotherapy) for patients with OA. Most research has tended to evaluate exercise therapy in isolation and further research is needed to evaluate the effects of exercise for OA when delivered as part of an overall treatment package. For example, exercise combined with weight loss appears to be more effective than either intervention alone.[4] There are some types of exercise used in the treatment of OA that need more large-scale rigorous clinical trials before their efficacy can be fully evaluated. These include aquatic exercise, balance programs, Tai Chi and neuromotor retraining programs. Finally, whilst some studies have evaluated effects of exercise on depressive symptoms, self-efficacy, quality of life, need for joint replacement, and use of analgesic medications these have been insufficiently studied across the range of exercise modalities used in people with OA.

Table 1
Summary of evidence-based recommendations for exercise in knee and hip OA based on Roddy et al.[26].

Proposition
Both strengthening and aerobic exercise can reduce pain and improve function and health status
There are few contraindications to prescription of exercise
Prescription of both general (aerobic fitness training) and local (strengthening) exercises is recommended
Exercise therapy should be individualized and patient-centred taking into account factors such as age, co-morbidity and overall mobility
To be effective, exercise programs should include advice and education to promote a positive lifestyle change with an increase in physical activity
Group exercise and home exercise are equally effective and patient preference should be considered
Adherence is the principle predictor of long-term outcome from exercise
Strategies to improve and maintain adherence should be adopted
Effectiveness of exercise is independent of presence or severity of X-ray findings

4. Exercise prescription – recommendations

Recommendations for exercise prescription in those with hip or knee OA have been developed by Roddy et al.[26] and are summarized in Table 1. Essentially exercise therapy should be individualized and patient-centred taking into account factors such as patient age, mobility, co-morbidities and preferences. An assessment of specific impairments such as strength, range of motion, aerobic fitness and balance is needed to determine the most appropriate exercise regime.

Type of exercise. There are relatively few direct head-to-head comparisons of different exercise modalities in people with OA. Based on the few well-designed clinical trials that exist,[4,28] evidence suggests that there is no clear benefit of one form of exercise type over another for improving pain and function in OA. For example, walking and strength training were equally effective over 18 months in a large study of people with knee OA.[4] However, effect sizes from meta-analyses for pain and function appear to be higher for land-based exercise than for aquatic exercise and higher for aerobic exercise than for strengthening exercise.[11] Obese patients or those with severe disease may find aquatic exercise that minimizes joint load useful particularly in the initial phase prior to commencing land-based exercise. Similarly, seated

Table 2
General guidelines for training parameters in people with OA pain, as developed by the American Geriatrics Society.[30]

Exercise type	Intensity	Volume	Frequency
Flexibility: static stretching initially	Stretch to subjective sensation of resistance	1 stretch/muscle group; hold 5–15 s	Once daily
Flexibility: longer term goal	Stretch to full range of motion	3–5 stretches/muscle group; hold 20–30 s	3–5/week
Strengthening: isometric	Low-moderate: 40–60% MVC	1–10 submax contractions/muscle group; hold 1–6 s	Daily
Strengthening: isotonic	Low: 40% 1 RM Mod: 40–60% 1 RM High: >60% 1 RM	10–15 reps 8–10 reps 6–8 reps	2–3/week
Aerobic	Low–mod: 40–60% of VO_2 max/HRmax RPE: 12–14 = 60–65% VO_2 max	Accumulation of 20–30 min/day	2–5/week

1 RM = one repetition maximum; MVC = maximal voluntary contraction; RPE = rating of perceived exertion; HRmax = age-predicted heart rate maximum; VO_2 max = maximal aerobic capacity.

strength training, even at high intensity, may be more tolerable than weight-bearing aerobic exercise in these patients. In overweight patients undergoing dietary-induced weight loss, strength training is important to minimize loss of lean muscle mass that would otherwise exacerbate muscle weakness.[29]

For the majority of people with OA, a combination of both general (aerobic fitness training) and local (strengthening) exercises is optimal to address the spectrum of impairments associated with OA.[26] However, this may not necessarily be practical and the choice of one type over another will be based on an assessment of the individual patient. Furthermore, whether to use weight-bearing exercise or non-weight-bearing exercise should be based on individual assessment as currently the evidence shows that both are equally effective.[12] For strengthening exercise, the quadriceps, hip abductors, hip extensors, hamstrings and calf muscles are important for function and should be particularly targeted. The type of aerobic exercise can be varied and may include activities such as walking, cycling or seated stepper depending on which is most comfortable and achievable for the patient. Other forms of exercise such as stretching, range of motion and balance may be incorporated to achieve specific goals based on individual patient assessment. High impact exercise should be avoided given the potentially deleterious effects of high joint load as shown in animal studies.[30,31]

Mode of delivery. Exercise may be delivered via individual treatments, supervised group classes or performed unsupervised at home. Advantages of group-based exercise programs include the social interaction for participants and the ability to minimize resources and cost compared to personal trainer/therapy session. Disadvantages include greater difficulty in tailoring exercise to individuals and the need to attend a specific location at a set time. Home exercise entails little financial outlay and provides greater flexibility regarding timing of the exercise session. However, there is a lack of suitable equipment and a lack of supervision that may hinder progression to more challenging exercise regimens and pose safety concerns.

It appears that all three modes of exercise delivery are effective in reducing symptoms.[12] However, practitioner supervision may improve outcomes. One study found that supplementing a home-based exercise program with a physiotherapist-supervised group exercise program for 8 weeks led to significantly greater improvements in locomotor function and walking pain at 12 months.[32] The number of directly supervised exercise sessions can also influence treatment effect sizes. In a recent meta-analysis, studies evaluating exercise programs with less than 12 direct supervision occasions demonstrated small treatment effects whereas those with more than 12 direct supervision occasions demonstrated moderate treatment effects.[12] One mode of exercise delivery that has been shown to be ineffective is a "minimalist" approach whereby patients are simply given a pamphlet or audiovisual material outlining a standardised exercise program.[33] Therefore it appears that optimal improvements in symptoms and function may be achieved through the use of both individualized and group exercise treatment sessions that are supervised by an exercise practitioner followed by a home program. Newer remote delivery technologies such as Internet and mobile phones are available but their specific applicability to this older patient group requires evaluation.

Dosage. The frequency, duration and intensity of the exercise program may affect clinical outcomes, although as stated these have not been well studied in people with OA. Specific guidelines for strengthening, aerobic exercise and flexibility in people with OA have been devised by the American Geriatrics Society[34] (Table 2). The dosages in these guidelines are somewhat less than current consensus recommendations by the American College of Sports Medicine and the American Heart Association for healthy older adults.[35] With regards to aerobic exercise, these recommend that if older adults cannot do up to 150 min of moderate-intensity aerobic activity per week because of chronic conditions such as OA, they should be as physically active as their abilities and conditions allow.

If obesity is an issue, then accumulating greater volumes of weekly exercise is desirable. Weight loss of greater than 5% or at a rate of >0.24% reduction per week over a 20-week period can lead to significant improvements in disability[36] and reductions in knee load[37] in people with knee OA. The recommendation by the Osteoarthritis Research Society International that people with hip OA lose weight is based on expert opinion unsupported by research evidence.[11]

High-intensity training (high resistance/load) might be expected to result in greater strength gains in people with

lower limb OA than low-intensity training but could potentially overload the joint and exacerbate symptoms. The only study comparing high- and low-intensity strengthening programs found that both were equally beneficial for pain, function, walking time and muscle strength over 8 weeks in people with knee OA.[38] Importantly, adverse events were no more likely in the high-intensity group, contrary to what is often assumed. From a practical perspective, the high-intensity program took 20 min less which may improve patient adherence. There are no studies that have directly evaluated whether the intensity of aerobic exercise influences outcomes in patients with OA. However, in one study both high (70% heart rate reserve) and low (40% heart rate reserve) intensity cycling been improved peak VO_2.[39]

5. Special considerations

Safety. In general, exercise is safe and well tolerated by most people with lower limb OA including those with severe disease and there are few contraindications to exercise resulting from the OA *per se* although co-morbidities need to be considered. It is not uncommon for patients to experience some discomfort at the affected joint during exercise and patients should be advised that this is normal and does not indicate a worsening of their OA disease. Exercise practitioners should not adopt a pain-contingent approach to exercise prescription in this patient group. However, substantial increases in pain and/or swelling during or following exercise that last more than several hours can suggest that modifications to the exercise program are needed. Given that the patient group with OA is often older and overweight, other safety considerations include adequate footwear, appropriate warm-up and cool-down, correct exercise technique and gradual increases in exercise dose.

Long-term exercise effectiveness and patient adherence. Despite consistent findings of short-term improvements with exercise, the limited number of studies evaluating longer term outcomes with exercise show that benefits decline.[40] This is because patient adherence to exercise reduces rapidly over time and is an important factor determining the long-term effectiveness of exercise for patients with OA.[41]

The challenge then remains to increase the proportion of patients with OA exercising. Although not well studied, a complex array of possible factors can contribute to adherence rates to exercise in individuals with OA. Adherence is improved when patients receive attention from health professionals rather than a primarily home-based exercise program.[42] Better adherence is related to the patient's belief in the effectiveness of the intervention and their understanding of the pathogenesis of OA (those who are less adherent tend to believe that OA is part of the natural ageing process or that it is simply a "wear and tear" disease).[43] Self-efficacy, or one's belief in their own ability to perform tasks, is also associated with higher adherence and better outcome.[44]

Many strategies have been suggested to improve adherence to exercise for those with OA. Catering the exercise program to the unique requirements of the patient as well as ensuring availability of resources can be effective in maximizing adherence.[41] Other methods suggested to improve adherence include educating patients about the disease and benefits of exercise, long-term monitoring review by a clinical exercise professional, regular follow-up or booster sessions, use of pedometers or self-reported diary and support from family and friends.[41]

6. Summary

Exercise is a key component of the management of OA symptoms and has been shown to be beneficial for individuals with OA disease of all severities. Exercise practitioners play an important role in prescribing appropriate exercise for patients taking into account individual symptoms, problems and preferences. Encouraging exercise adherence behaviours and reinforcing healthy lifestyle habits will assist in optimizing outcomes from treatment. Furthermore, exercise programs should be combined with education and behavioural strategies to promote positive lifestyle change and increase overall physical activity levels. The benefits of exercise are additive when delivered with other interventions such as weight loss[45] particularly given the high prevalence of overweight individuals with knee OA.

References

1. Australia A. Painful realities: the economic impact of arthritis in Australia in 2007. *Arthritis Australia* 2007:1–88.
2. Reeuwijk KG, de Rooij M, van Dijk GM, et al. Osteoarthritis of the hip or knee: which coexisting disorders are disabling? *Clin Rheumatol* 2010;**29**(7):739–47.
3. Farr JN, Going SB, Lohman TG, et al. Physical activity levels in patients with early knee osteoarthritis measured by accelerometry. *Arthritis Rheum* 2008;**59**(9):1229–36.
4. Messier S, Loeser R, Miller G, et al. Exercise and dietary weight loss in overweight and obese older adults with knee osteoarthritis. *Arthritis Rheum* 2004;**50**(5):1501–10.
5. Vogels E, Hendriks H, van Baar M, et al. Clinical practice guidelines for physical therapy in patients with osteoarthritis of the hip or knee. Royal Dutch Society for Physical Therapy; 2003. www.fysionet.nl/index.html?dossier_id=81&dossiers=1.
6. Jan MH, Tang PF, Lin JJ, et al. Efficacy of a target-matching footstepping exercise on proprioception and function in patients with knee osteoarthritis. *J Orthop Sports Phys Ther* 2008;**38**(1):19–25.
7. Sekir U, Gur H. A multi-station proprioceptive exercise program in patients with bilateral knee osteoarthrosis: functional capacity, pain and sensorimotor function. A randomized controlled trial. *J Sports Sci Med* 2005;**4**:590–603.
8. Lange AK, Vanwanseele B, Singh MAF. Strength training for treatment of osteoarthritis of the knee: a systematic review. *Arthritis Rheum-Arthritis Care Res* 2008;**59**(10):1488–94.
9. Ettinger Jr WH, 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.

10. O'Reilly SC, Jones A, Muir KR, et al. Quadriceps weakness in knee osteoarthritis: the effect on pain and disability. *Ann Rheum Dis* 1998;**57**(10):588–94.
11. Zhang W, Nuki G, Moskowitz RW, et al. OARSI recommendations for the management of hip and knee osteoarthritis. Part III. Changes in evidence following systematic cumulative update of research published through January 2009. *Osteoarthritis Cartilage* 2010;**18**(4):476–99.
12. Fransen M, McConnell S. Exercise for osteoarthritis of the knee. *Cochrane Database Syst Rev* 2008;(4).
13. Pelland L, Brosseau L, Wells G, et al. Efficacy of strengthening exercises for osteoarthritis (Part I): a meta-analysis. *Phys Ther Rev* 2004;**9**(2):77–108.
14. Lange AK, Vanwanseele B, Fiatarone Singh MA. Strength training for treatment of osteoarthritis of the knee: a systematic review. *Arthritis Rheum* 2008;**59**(10):1488–94.
15. Fransen M, McConnell S, Hernandez-Molina G, et al. Exercise for osteoarthritis of the hip. *Cochrane Database Syst Rev* 2009;(3):CD007912.
16. McNair P, Simmonds M, Boocock M, et al. Exercise therapy for the management of osteoarthritis of the hip joint: a systematic review. *Arthritis Res Ther* 2009;**11**:R98.
17. Hernandez-Molina G, Reichenbach S, Zhang B, et al. Effect of therapeutic exercise for hip osteoarthritis pain: results of a meta-analysis. *Arthritis Rheum* 2008;**59**(9):1221–8.
18. Bartels E, Lund H, Hagen K, et al. Aquatic exercise for the treatment of knee and hip osteoarthritis. *Cochrane Database Syst Rev* 2007;(4).
19. Hall A, Maher C, Latimer J, et al. The effectiveness of Tai Chi for chronic musculoskeletal pain conditions: a systematic review and meta-analysis. *Arthritis Rheum* 2009;**61**(6):717–24.
20. Wang C, Collet JP, Lau J. The effect of Tai Chi on health outcomes in patients with chronic conditions: a systematic review. *Arch Intern Med* 2004;**164**(5):493–501.
21. Ettinger WH, 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. *JAMA* 1997;**277**(1):25–31.
22. Mikesky A, Mazzuca S, Brandt K, et al. Effects of strength training on the incidence and progression of knee osteoarthritis. *Arthritis Rheum* 2006;**55**:690–9.
23. Miyazaki T, Wada M, Kawahara H, et al. Dynamic load at baseline can predict radiographic disease progression in medial compartment knee osteoarthritis. *Ann Rheum Dis* 2002;**61**:617–22.
24. Lim BW, Hinman RS, Wrigley TV, et al. Does knee malalignment mediate the effects of quadriceps strengthening on knee adduction moment, pain, and function in medial knee osteoarthritis? A randomized controlled trial. *Arthritis Rheum* 2008;**59**(7):943–51.
25. Bennell KL, Hunt MA, Wrigley TV, et al. Hip strengthening reduces symptoms but not knee load in people with medial knee osteoarthritis and varus malalignment: a randomised controlled trial. *Osteoarthritis Cartilage* 2010;**18**(5):621–8.
26. Roddy E, Zhang W, Doherty M, et al. Evidence-based recommendations for the role of exercise in the management of osteoarthritis of the hip or knee—the MOVE consensus. *Rheumatology (Oxford)* 2005;**44**(1):67–73.
27. Zhang W, Moskowitz RW, Nuki G, et al. OARSI recommendations for the management of hip and knee osteoarthritis. Part II. OARSI evidence-based, expert consensus guidelines. *Osteoarthritis Cartilage* 2008;**16**(2):137–62.
28. Fransen M, Nairn L, Winstanley J, et al. Physical activity for osteoarthritis management: a randomized controlled clinical trial evaluating hydrotherapy or Tai Chi classes. *Arthritis Rheum* 2007;**57**(3):407–14.
29. Toda Y. The effect of energy restriction, walking, and exercise on lower extremity lean body mass in obese women with osteoarthritis of the knee. *J Orthop Sci* 2001;**6**(2):148–54.
30. Radin EL, Martin RB, Burr DB, et al. Effects of mechanical loading on the tissues of the rabbit knee. *J Orthop Res* 1984;**2**(3):221–34.
31. Radin EL, Ehrlich MG, Chernack R, et al. Effect of repetitive impulsive loading on the knee joints of rabbits. *Clin Orthop Relat Res* 1978;(131):288–93.
32. McCarthy C, Mills P, Pullen R, et al. Supplementing a home exercise programme with a class-based exercise programme is more effective than home exercise alone in the treatment of knee osteoarthritis. *Rheumatology* 2004;**43**(7):880–6.
33. Ravaud P, Giraudeau B, Logeart I, et al. Management of osteoarthritis (OA) with an unsupervised home based exercise programme and/or patient administered tools. A cluster randomised controlled trial with a 2×2 factorial design. *Ann Rheum Dis* 2004;**63**:703–8.
34. Society AG. Exercise prescription for older adults with osteoarthritis pain: consensus practice recommendations. A supplement to the AGS Clinical Practice Guidelines on the management of chronic pain in older adults. *J Am Geriatr Soc* 2001;**49**(6):808–23.
35. Nelson ME, Rejeski WJ, Blair SN, et al. Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc* 2007;**39**(8):1435–45.
36. Christensen R, Bartels EM, Astrup A, et al. Effect of weight reduction in obese patients diagnosed with knee osteoarthritis: a systematic review and meta-analysis. *Ann Rheum Dis* 2007;**66**(4):433–9.
37. Messier SP, Gutekunst DJ, Davis C, et al. Weight loss reduces knee-joint loads in overweight and obese older adults with knee osteoarthritis. *Arthritis Rheum* 2005;**52**(7):2026–32.
38. Jan MH, Lin JJ, Liau JJ, et al. Investigation of clinical effects of high- and low-resistance training for patients with knee osteoarthritis: A randomized controlled trial. *Phys Ther* 2008 [January Epub].
39. Mangione KK, McCully K, Gloviak A, et al. The effects of high-intensity and low-intensity cycle ergometry in older adults with knee osteoarthritis. *J Gerontol A Biol Sci Med Sci* 1999;**54**(4):M184–90.
40. Pisters MF, Veenhof C, van Meeteren NL, et al. Long-term effectiveness of exercise therapy in patients with osteoarthritis of the hip or knee: a systematic review. *Arthritis Rheum* 2007;**57**(7):1245–53.
41. Mazieres B, Thevenon A, Coudeyre E, et al. Adherence to, and results of, physical therapy programs in patients with hip or knee osteoarthritis. Development of French clinical practice guidelines. *Joint Bone Spine* 2008;**75**(5):589–96.
42. McCarthy C, Mills P, Pullen R, et al. Supplementation of a home-based exercise programme with a class-based programme for people with osteoarthritis of the knees: a randomised controlled trial and health economic analysis. *Health Technol Assess* 2004;**8**(46):1–61.
43. Campbell R, Evans M, Tucker M, et al. Why don't patients do their exercises? Understanding non-compliance with physiotherapy in patients with osteoarthritis of the knee. *J Epidemiol Community Health* 2001;**55**:132–8.
44. Marks R, Allegrante J. Chronic osteoarthritis and adherence to exercise: a review of the literature. *J Aging Phys Activity* 2005;**13**:434–60.
45. Messier SP, Loeser RF, Miller GD, et al. Exercise and dietary weight loss in overweight and obese older adults with knee osteoarthritis: the Arthritis, Diet, and Activity Promotion Trial. *Arthritis Rheum* 2004;**50**(5):1501–10.