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Aerobic Activity in Prevention & Symptom Control of Osteoarthritis

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Abstract

Almost 27 million US adults suffer from some form of osteoarthritis (OA). An epidemic of arthritis-associated disability is expected in the US over the next 2 decades, largely fueled by the aging population and the tremendous growth in the prevalence of knee osteoarthritis (OA). Regular physical activity (PA), particularly strengthening and aerobic activity, can reduce pain and improve function and health status among patients with knee and hip osteoarthritis. The focus of this review is to examine the impact of aerobic activity on OA progression and symptom control. In general, both strengthening and aerobic exercise are associated with improvements in pain, perceived physical function, and performance measures for those with lower limb OA; although comparisons of strengthening versus aerobic exercise on these outcomes is unusual. Structural disease progression in persons with established OA has been directly evaluated by a limited number of PA clinical trials in knee OA, but these protocols focused on strength training exclusively. In healthy subjects, it appears that overall PA is beneficial, rather than detrimental, to knee joint health. Possibly the most important reason for engaging in PA is to prevent obesity, which has independently been associated with many serious chronic diseases, including OA incidence and progression. More research is needed to determine the optimal types and dosing of aerobic conditioning.

Introduction

An epidemic of arthritis-associated disability is expected in the US over the next 2 decades, largely fueled by the aging population and the tremendous growth in the prevalence of knee osteoarthritis (OA).[1–3]Almost 27 million US adults suffer from some form of osteoarthritis (OA). Mostly a condition of older persons, OA afflicts approximately one third of those over age 65. The CDC reports the prevalence of hand OA to be 8% of adults over age 60, hip OA to be 4.4% of those over age 55, with knee OA most prevalent at 9.5% of adults 55 or older. Disease in weight bearing joints has greater clinical impact, with about 80% of persons with OA reporting some degree of movement limitation: 25% cannot perform major activities of daily living (ADL's), 11% of adults with knee OA need help with personal care, and 14% require help with routine needs.[4] Knee OA is already a major cause of arthritis-related disability,[5] limiting daily activities such as walking and climbing stairs for more than 7 million Americans.[6] Disability not only reduces the quality of life for individuals and jeopardizes their ability to live independently;[7–10] it increases the risk of hospitalization, institutionalization, and mortality; and is a major driver of health care costs due to arthritis.[1112,13]

Persons at risk for osteoarthritis have one or more of the following risk factors: age over 50, female gender, a first-order family member with OA, previous history of a major knee or hip injury or surgery, obesity, history of joint trauma, or a job requiring bending and carrying. Hip osteoarthritis can also be secondary to developmental defects.[14] Those at highest risk of developing OA have more than one risk factor.[14] Mechanical factors also play a role in the development of OA and its progression, including joint laxity and varus/valgus alignment.[15,16] Additionally, greater quadriceps strength has been associated with increased likelihood of tibiofemoral osteoarthritis progression in malaligned knees and lax knees.[17]

Participation in PA is a low-cost measure that may help to decrease symptoms and arthritis-associated disability. Physical activity improves the health of adults with arthritis in a variety of unique ways. Regular PA can decrease bone loss and promote healthy joint cartilage,[18] improve physical function, reduce many arthritis symptoms including pain and fatigue, and can convey psychological benefits.[19] More importantly, there is a growing body of evidence that PA can prevent or delay the development of arthritis associated disability.[20,21]

The MOVE consensus group was formed from representatives of professional bodies to which OA is of relevance to produce evidence-based recommendations for physical activity to guide health-care practitioners. After an extensive review of the evidence, the MOVE consensus language specifically states that strengthening and aerobic activity can reduce pain and improve function and health status among patients with knee and hip osteoarthritis.[22] To address OA symptoms, recommendation of one type of activity versus the other is problematic, as both components are often included as part of the same intervention program. The focus of this review is to examine the impact of aerobic activity on OA progression and symptom control beyond the weight loss and other health benefits usually associated with aerobic activity. An exploration of activity-associated joint health helps put this evidence in perspective.

Physical Activity and Osteoarthritis

Regular physical activity (PA) provides important physiologic benefits for older adults, including those with arthritis. It can counteract the reduction in fitness, muscular strength, and endurance associated with aging.[23,24] Physical activity has been demonstrated to prevent the development of functional limitations or mitigate the progression of limitations,[4] and thereby improve quality of life in older adults.[25,26] In the general population of older adults, regular physical activity does not increase the risk for developing osteoarthritis,[27] and certainly reduces the risk for developing other chronic conditions including cardiovascular disease, thromboembolic stroke, hypertension, type 2 diabetes mellitus, obesity, colon cancer, breast cancer, and depression.[25,28] Regular participation in physical activity can reduce falls and injury from falls.[29] There is also evidence that physical activity prevents or delays cognitive impairment and improves sleep.[30]

In order to appreciate the role of PA in health, one must understand the differences in terminology applied to PA. Physical activity is defined as: "any bodily movement produced by contraction of skeletal muscle that substantially increases energy expenditure above the basic level."[31] Exercise is defined as: "planned, structured, and repetitive, with the intent of improving or maintaining one or more facets of physical fitness or function."[31] Both PA and exercise generally refer to large-muscle activities that may be aerobic (eg, walking or running) or anaerobic (eg, weight lifting). Both PA and exercise are characterized by their frequency (eg, the number of times per week), duration (eg, the length of a bout of exercise), and intensity (e.g, moderate-intensity is equivalent to walking as though you are late for an important meeting, causing you to breathe a little harder and possibly perspire). Four major types of PA include muscle contraction, range of motion, weight bearing, and aerobic exercise. The pattern of PA refers to the alternation of the various intensity levels/types of PA with rest over a specified amount of time. For example, the "weekend warrior" is typically sedentary all during the work week, but takes to the athletic field on Saturdays and Sundays for prolonged bouts of PA.

Joint Health and Activity/Inactivity

Movement is integral to the human experience, however this can be difficult to realize in an era committed to labor saving devices. Man has become so expert in avoiding movement that the consequential negative health impact has generated governmental intervention.[32] In 2008, federal guidelines were updated and released to promote PA levels in the general public. Indeed, persons with OA have even greater need to heed advice to keep moving, as the integrity of joint tissues depends on it. The articular joint is a highly intricate organ system that requires regular maintenance. The poetic summary statement "use it or lose it" can be aptly applied to the joint system. When joints are immobilized either intentionally or medically, a number of negative physiologic consequences ensue.

Most of what is known about articular cartilage health comes from animal studies. In the 1970s, healthy adult dogs were studied for a defect in proteoglycan (major component of extracellular mix) aggregation by immobilizing one limb for varying periods of time. Immobilization for 6 days resulted in a 41% reduction in proteoglycan synthesis by articular cartilage from the restrained knee compared with the contralateral control knee. After 3 weeks of immobilization, proteoglycan aggregation was no longer demonstrable in cartilage from the constrained limb. The aggregation defect was rapidly reversible and aggregates were again normal size 2 weeks after removal of a cast that had been worn for 6 weeks.[33] More recently, a literature review of the morphological, biochemical, and biomechanical changes in articular cartilage following immobilization of animals was conducted.[34] Stress deprivation resulted in several articular alterations that do not always recover upon remobilization of the joint. State of the art imaging techniques (eg, pulse sequence MRI) in select populations is beginning to provide information about the influence of PA on cartilage and help rehabilitation professionals formulate strategic treatment plans. Quantitative cartilage imaging has been used to investigate short-term (deformational behavior) and long-term (functional adaptation) effects of exercise on human articular cartilage. Findings suggest that human cartilage deforms very little in vivo during physiological activities and recovers from deformation within 90 minutes after loading. Whereas cartilage deformation appears to become less with increasing age, gender and physical training status do not seem to affect in vivo deformational behavior. There is now quality evidence that cartilage undergoes some type of atrophy (thinning) under reduced loading conditions, such as with postoperative immobilization and paraplegia. Interestingly, increased loading (as might be seen in elite athletes) does not appear to be associated with increased average cartilage thickness. However, studies of twins suggest a strong genetic contribution to cartilage morphology.[35]

Aerobic Activity in OA Symptom Control

For individuals with OA, there is strong evidence from randomized controlled clinical trials (RCTs) that physical activity is beneficial to relieve joint symptoms and improve function. Traditionally, muscle strengthening exercise (eg, isometric, isotonic, isokinetic exercise) was advised to maintain muscle mass and strength.[36] Current evidence supports the value of aerobic activity (eg, brisk walking) in relieving joint symptoms and improving function (Table 1). RCTs including persons with knee or hip OA demonstrate that both aerobic exercise and muscle strengthening can reduce pain, improve physical performance, and may prevent or delay disability, although evidence for disability prevention is plagued by measurement and conceptual clarity issues.[37–39] Regarding disability, Keysor notes that researchers often use the term ‘disability’ to represent the concept of ‘function’, and that instruments used to ascertain self-reported function and disability often contain items representing both domains, which hinders interpretation of instrument summary scores that include both types of items.[40]

Because intervention studies frequently include both aerobic and strengthening components, or do not explicitly state the nature/intensity of the activity (as in ‘hydrotherapy’), it is challenging to delineate the unique role of aerobic activity in OA symptom relief.

The intervention literature most frequently examined the effect of PA on pain and perceived physical function/performance measures. In general, both strengthening and aerobic exercise are associated with improvements in both parameters for those with lower limb OA. Although some studies found greater pain relief scores with aerobic conditioning vs strengthening trials, these types of comparisons were unusual, and in most cases, differences were not significant (Table 1). Frequently, the two types of activities were delivered together as part of the same intervention. Roddy and colleagues reviewed aerobic vs strengthening trials[41] and their effects on knee OA symptoms of pain and self-reported disability. They found that pooled effect sizes for pain and self reported disability were somewhat better for aerobic walking than for quadriceps strengthening, but that no advantage of one form of exercise over the other was found on indirect comparison of pooled data. Similar results were found in a 12-week study comparing water-based classes with both aerobic and strengthening components in comparison to Tai Chi;[42] however, participants in the water-based class had significantly better physical performance scores than those in Tai Chi. A Cochrane Review of water-based exercise interventions found a decrease in pain in both knee and hip OA, but the effect was small (3% absolute reduction, and 6.6% relative reduction from baseline), with no long-term results noted in the trials.[43]

Unfortunately, the most consistent finding across interventions was that most trials focused on short-term (<6 months) interventions, and that improvements in pain relief and functional status attained during those aerobic interventions rarely lasted beyond 6 months as adherence to PA behaviors waned.[40,44] The limited number of long-term (>6 months) trials was plagued by high attrition and poor post-intervention maintenance of treatment effects.[45]

Psychological well-being was less often an outcome of interest in these interventions. Ettinger and colleagues'[37]landmark knee OA RCT showed that aerobic exercise (walking program) resulted in significantly better cardiovascular fitness and favorable differences in depression when compared to control (education).[37–39] However muscle strengthening alone did not reduce depression. A recent review also shed light on the efficacy of physical activity interventions that may be beneficial for older people with OA and concomitant depressive symptoms. Exercise therapy interventions (N = 7) were associated with reduced depressive symptoms in the short term. However, the long-term benefits of depression management in patients with OA and co-morbid depression are unknown. One reason for the relative lack of information in this area is that the heterogeneity of depression in patients with chronic pain has hampered trial design. For practical reasons, existing studies tend to evaluate predominantly short-term outcomes, which also contributes to the relative lack of information.[46]

Controlled trials also demonstrate the capacity for complementary approaches such as Tai Chi to reduce depressive symptoms among patients with knee OA. To evaluate the effectiveness of Tai Chi in the treatment of knee osteoarthritis (OA) symptoms and concomitant depression, a prospective, single-blind, randomized controlled trial of 40 individuals with symptomatic tibiofemoral OA was conducted. Patients were randomly assigned to 60 minutes of Tai Chi (10 modified forms from classic Yang style) or attention control (wellness education and stretching) twice weekly for 12 weeks, with assessments at 24 and 48 weeks. Compared with the controls, patients assigned to Tai Chi exhibited significantly greater improvement in Center for Epidemiologic Studies Depression Scale (−6.70 [95% CI −11.63, −1.77; P = 0.009]).[47]

Consistent across aerobic intervention trials is evidence for a dose-response effect; participants with knee or hip OA who performed more exercise had better outcomes.[36]These findings support the need for: a) PA interventions that examine long-term results, b) produce and support long term changes in PA behavior that include both aerobic and muscle strengthening components, and c) the need to establish specific prescriptive protocols. In 1994, research recommendations for addressing knee osteoarthritis-associated disability included determining "which exercise is most beneficial; and at what frequency, intensity, and duration."[48] Nearly 20 years later, the research community continues to focus on answering this question.

Aerobic Activity in Disease Progression

The overarching goal of all arthritis therapy is to decrease pain, improve function, and optimize participation in meaningful life roles. The fact that exercise therapy is a cornerstone in hip and knee osteoarthritis treatment is undisputed, given its role in reducing pain and improving function. Besides improving range of motion, muscle strength, balance, proprioception and endurance, arthritis exercise therapies improve glucose tolerance and fitness, thereby decreasing the risk for other chronic conditions. People who engage in PA programs to relieve arthritis associated symptoms often worry that the increased activity will lead to increased joint damage. This begs the question, “What effect does physical activity have on the osteoarthritis disease progression itself?”

Structural disease progression in persons with established OA has been directly evaluated by a limited number of PA clinical trials in knee OA, but these protocols focused on strength training exclusively,[49–51] with only one study examining OA progression as a primary outcome.[50] Quadriceps[52] and hip abductor strengthening[53] protocols that reduce the knee adduction moment (thought to slow knee OA progression) have also been evaluated, but studies examining the impact of aerobic activity alone are scarce. This observation has been discussed as a gap in the current literature in a recent review of the clinical evidence for exercise in osteoarthritis of the hip and knee.[54] Indeed, Table 1 illustrates that only Ettinger’s study examined radiologic evidence of progression as an outcome. Hip osteoarthritis has fewer documented risk factors for progression[55], and no factors were modifiable.

However, before sophisticated imaging studies of cartilage after loading existed, there were observational studies of aerobic activity on the development of OA. In 1993, a 5-year longitudinal study examined the effects of running and aging on the development of radiographic and clinical OA of the knees, hands and lumbar spine.[56] Five year radiographic results compared to baseline radiographs from 35 runners and 38 non-running controls (mean age of 63 years) showed OA progression for the knees, hands, and lumbar spine. Thirteen per cent of all subjects developed OA of the hands and 12% of all subjects developed OA of the knees. Notably, running did not appear to accelerate the development of radiographic or clinical OA of the knees in runners compared to non-runners. A follow-up study by the same author[57] yielded similar results: the presence of radiographic hip OA and the progression of radiographic knee OA was similar for older runners and non-runners.

Though not specifically a study of exercise in OA, the presence of varus thrust (identifiable by simple gait observation) during walking, the most common form of exercise for persons with arthritis, was a potent risk factor for knee OA disease progression in the medial compartment.[58] Varus thrust may also predict poor physical function. Varus thrust increased the risk of disease progression among varus-aligned knees considered separately, suggesting that knees with a thrust are a subset of varus-aligned knees at particularly high risk for progression of OA.[58] Thus, before recommending types of physical activity to patients, one must be aware of the knee biomechanics to avoid further joint damage.

With increased physical activity also comes the risk of injury, especially knee injury. There is some debate as to the contribution of anterior cruciate ligament injury to the development of knee OA. One systematic review concluded that the prevalence rates of knee OA after anterior cruciate ligament reconstruction reported by previous reviews have been too high. The highest rated studies in their review reported low prevalence of knee osteoarthritis (0–13%) for individuals with isolated anterior cruciate ligament injury and a higher prevalence of knee osteoarthritis (21%–48%) for persons with combined injuries.[59] Current opinion is that animal and human studies provide no evidence for increased risk of hip or knee OA with moderate exercise, and that sporting activity has a protective effect in the absence of traumatic injury. One age-matched case control study found recreational runners who ran 12–14 miles per week for up to 40 years had no increase in radiological or symptomatic hip or knee OA. However, higher rates of hip OA occurred in contact sports than in age-matched controls, with the highest rate in professional players. Soccer players with torn anterior cruciate ligaments (ACL) are believed more likely to develop knee OA than those with intact ACL. Early ACL repair seems to reduce the risk of knee OA, but does not prevent it. Established injury prevention programs have been refined to prevent injuries such as ACL rupture.[60]

Aerobic Activity in Disease Prevention

The effect of participation in vigorous physical activity on changes to patella cartilage over 2 years was examined in 297 healthy adults ages 50–79 years with no history of knee injury or symptoms.[61] Physical activity data were obtained by questionnaire at baseline, and patellar cartilage volume and defects were determined by magnetic resonance imaging. Vigorous PA was found to be beneficial to patellofemoral joints for people without preexisting cartilage damage. In a smaller study (N=20) of healthy volunteers, the short-term effects of recreational running on the deformation of knee articular cartilage was examined, in addition to the relationship between changes in knee cartilage volume and biomechanical modulators of knee joint load.[62] All subjects first underwent MRI to evaluate femoral and tibial cartilage volumes prior to and following a 30 minute period of relaxed sitting, followed by a recreational run of 5000 steps. Laboratory analysis of participants' running gait compared biomechanical derived measures of knee joint loading with changes in cartilage volume. Results showed that running resulted in significant deformation of the medial (5.3%, $P<0.01$) and lateral femoral cartilage (4.0%, $P<0.05$) and lateral aspect of the tibial cartilage (5.7%, $P<0.01$). No significant differences were noted between genders. Only 'maximum compression stress' was significantly correlated with percentage changes in lateral femoral cartilage volume ($r^2=0.456$, $P<0.05$). The authors concluded that the contribution of biomechanical factors to knee joint loading and the pathogenesis of knee OA require further enhancement of knee muscle modeling and analysis of stress distribution across cartilage. Hopefully, as imaging and laboratory studies provide further insight into the functioning of articular cartilage, prevention strategies and therapies for OA will be enhanced.[63]

An extensive review of literature examining the effect of PA on the knee joint[64] concluded that knee joint structures are affected differently by physical activity, but that overall, PA is beneficial, rather than detrimental, to knee joint health. The types of activities examined included running, soccer, and other recreational sports. Specifically, while they noted an association of PA with an increase in radiographic osteophytes, there was no related increase in joint space narrowing, rather emerging evidence of an associated increase in cartilage volume and decrease in cartilage defects on magnetic resonance imaging.

Preventing knee osteoarthritis has been clearly linked to obesity control. As early as the Framingham study, weight change was noted to significantly affect the risk for the development of knee OA.[65] A decrease in body mass index of 2 units or more (weight loss, approximately 11 pounds) over the 10 years prior to the study examination decreased the risk of developing osteoarthritis by over 50% (odds ratio, 0.46; 95% Cl, 0.24 to 0.86; P = 0.02). Furthermore, the increased risk for OA was noted to begin as early as the 3rd decade of life. Among people with knee OA, recent work by Messier and colleagues suggest that a 10% weight loss in an overweight and obese osteoarthritic population elicits positive changes in the mechanical pathway to knee OA by having lower knee joint compressive loads during walking compared to low and no weight loss groups.[66] These findings are readily understandable, given that losing just one pound of body weight results in a four pound reduction in the load exerted on the knee for each step taken during daily activities.[67]

Interestingly, weight loss has been linked to reducing the risk for knee OA *symptoms*, but the effect was greater in severe symptomatic OA than in asymptomatic radiographic OA.[68] Obesity is of course also linked to the development of other chronic conditions, including late-onset diabetes and other components of metabolic syndrome (ie, hypertension, dyslipidemia, and impaired glucose tolerance). In a large Japanese study, the risk of knee OA increased with the number of metabolic syndrome components present.[69] Now, evidence from epidemiological and experimental data support the hypothesis that diabetes might be an independent risk factor for OA, at least in some patients, leading to the concept of a diabetes-induced OA phenotype. If confirmed, this new paradigm will have a dramatic impact on prevention of OA initiation and progression.[70] It is nearly impossible to discuss obesity/metabolic syndrome control without including a prominent role for aerobic physical activity!

Summary and Conclusions

An epidemic of arthritis-associated disability is expected in the US over the next 2 decades, largely fueled by the aging population, skyrocketing obesity rates, and the tremendous growth in the prevalence of knee osteoarthritis. Possibly the most important reason for engaging in PA is to prevent obesity, which fosters an environment that leads to many serious chronic diseases, including OA incidence and progression. In addition, there is a growing body of evidence that PA in persons with OA can decrease pain, improve function and depression, promote joint health, and possibly delay the development of disability in OA, but more research is needed to determine the optimal types and dosing of aerobic conditioning. Those ”unmoved” by this evidence may want to ponder the following quote: “The weakest and oldest among us can become some kind of athlete, but only the strongest can survive as spectators. Only the hardiest can survive the perils of inertia, inactivity and immobility.”[71]

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Table 1

Aerobic–based Interventions to Improve OA Outcomes

Author	Population	Intervention	OA Outcomes	Results
Ettinger[1] 1997	N= 439 community-dwelling adults Aged 60 years or older + radiographically evident knee osteoarthritis, pain, and self-reported physical disability	Aerobic exercise program, a resistance exercise program, and a health education program.	Self-reported disability score (range, 1–5) Secondary outcomes: • knee pain score (range, 1–6) • performance measures of physical function • x-ray score • aerobic capacity • knee muscle strength	Aerobic exercise group (compared to health education group). had: • A 10% lower adjusted mean (+/− SE) score on the physical disability questionnaire (1.71 +/− 0.03 vs 1.90 +/− 0.04 units; P<.001) • 12% lower score on the knee pain questionnaire (2.1 +/− 0.05 vs 2.4 +/− 0.05 units; P=.001) • performed better (mean [+/− SE]) on the 6-minute walk test (1507 +/− 16 vs 1349 +/− 16 ft; P<.001), • mean (+/−SE) time to climb and descend stairs (12.7 +/− 0.4 vs 13.9 +/− 0.4 seconds; P=.05), time to lift and carry 10 pounds (9.1 +/− 0.2 vs 10.0 +/− 0.1 seconds; P<.001), and mean (+/−SE) time to get in and out of a car (8.7 +/− 0.3 vs 10.6 +/− 0.3 seconds; P<.001) Resistance exercise group (compared to the health education group) had: • An 8% lower score on the physical disability questionnaire (1.74 +/− 0.04 vs 1.90 +/− 0.03 units; P=.003), • 8% lower pain score (2.2 +/− 0.06 vs 2.4 +/− 0.05 units; P=.02) • greater distance on the 6-minute walk (1406 +/− 17 vs 1349 +/− 16 ft; P=.02), • faster times on the lifting and carrying task (9.3 +/− 0.1 vs 10.0 +/− 0.16 seconds; P=.001), and the car task (9.0 +/− 0.3 vs 10.6 +/− 0.3 seconds; P=.003)
Messier et al 2004[2]	N= 316 community-dwelling overweight and obese Adults ages 60 years and older + body mass index of ≥ 28 kg/m(2) + knee pain + radiographic evidence of knee OA	Participants randomized into one of the groups: healthy lifestyle (control), diet only, exercise only, and diet plus exercise groups. Participants were provided with an aerobic exercise prescription that included walking within a heart rate range of 50–75% of heart rate reserve.	Self-reported pain and physical function Performance measures: • 6- min walk • Stair climb	In the diet plus exercise group, (relative to the healthy lifestyle group) significant improvements seen in: • self-reported physical function (P < 0.05) • 6-minute walk distance (P < 0.05) • stair-climb time (P < 0.05) • knee pain (P < 0.05)

Author	Population	Intervention	OA Outcomes	Results
	+ self-reported physical disability	Exercise-only or the diet plus exercise groups consisted of an • aerobic phase (15 min) • a resistance-training phase (15 min) • a second aerobic phase (15 min) • cooldown phase (15 min).		In the exercise group, (relative to the healthy lifestyle group), significant improvement seen in: • 6-minute walk distance ($P < 0.05$)
Cochrane et al 2005[3]	N= 196 women 116 men With lower limb OA (knee and hip) Randomized into control (159) and water exercise (153) groups	1 year intervention, with 6 month follow-up Water exercise session included warm-up, strengthening, Range of motion, stretch, Aerobic conditioning, balance, coordination exercises and/or swimming	WOMAC pain	Water exercise effective, but overall effect size was small, [mean group difference = 0.89, effect size = 0.25 (95% CI 0.02 to 0.47), $p = 0.031$] on WOMAC pain at 1 year, a reduction of about 10% in group mean pain score. This had declined, and was non-significant, at 18 months
Fransen 2007[4]	152 older persons + chronic symptomatic hip or knee OA hydrotherapy classes (n = 55), Tai Chi classes (n = 56), a waiting list control group (n = 41)	Hydro therapy vs Tai Chi Pool class had some aerobic –type components, but not enough specific info to evaluate	Pain and physical function (WOMAC), General health status (Medical Outcomes Study Short Form 12 Health Survey [SF-12], version 2) Psychological well-being, Physical performance: • Up and Go test • 50-foot walk time • timed stair climb	At 12 weeks, (compared with controls), hydrotherapy class participants had mean improvements (95% confidence interval) of • 6.5 (0.4, 12.7) for pain • 10.5 (3.6, 14.5) physical function scores (range 0–100) • achieved significant improvements in the physical performance measures. Tai Chi class participants (compared with controls) had improvements of: • 5.2 (−0.8, 11.1) for pain • 9.7 (2.8, 16.7) for physical function (SF-12 only)