Improved Function and Reduced Pain after Swimming and Cycling Training in Patients with Osteoarthritis

Mohammed Alkatan, Jeffrey R. Baker, Daniel R. Machin, Wonil Park, Amanda S. Akkari, Evan P. Pasha, and Hirofumi Tanaka

ABSTRACT. ***Objective.*** Arthritis and its associated joint pain act as significant barriers for adults attempting to perform land-based physical activity. Swimming can be an ideal form of exercise for patients with arthritis. Yet there is no information on the efficacy of regular swimming exercise involving patients with arthritis. The effect of a swimming exercise intervention on joint pain, stiffness, and physical function was evaluated in patients with osteoarthritis (OA).

Methods. Using a randomized study design, 48 sedentary middle-aged and older adults with OA underwent 3 months of either swimming or cycling exercise training. Supervised exercise training was performed for 45 min/day, 3 days/week at 60–70% heart rate reserve for 12 weeks. The Western Ontario and McMaster Universities Arthritis Index was used to measure joint pain, stiffness, and physical limitation.

Results. After the exercise interventions, there were significant reductions in joint pain, stiffness, and physical limitation accompanied by increases in quality of life in both groups (all $p < 0.05$). Functional capacity as assessed by maximal handgrip strength, isokinetic knee extension and flexion power (15–30% increases), and the distance covered in the 6-min walk test increased (all $p < 0.05$) in both exercise groups. No differences were observed in the magnitude of improvements between swimming and cycling training.

Conclusion. Regular swimming exercise reduced joint pain and stiffness associated with OA and improved muscle strength and functional capacity in middle-aged and older adults with OA. Additionally, the benefits of swimming exercise were similar to the more frequently prescribed land-based cycling training. Trial registration: clinicaltrials.gov NCT01836380. (First Release January 15 2016; J Rheumatol 2016;43:666–72; doi:10.3899/jrheum.151110)

Key Indexing Terms:
ARTHRITIS AEROBIC EXERCISE ISOKINETIC MUSCLE STRENGTH
AQUATIC ACTIVITY

Osteoarthritis (OA) is the most common form of arthritis and is the leading cause of disability in older adults[1]. Because no cure is currently available for OA, the treatment plan for this prevalent, disabling, and costly disease has focused on reducing joint pain and stiffness and improving physical function while minimizing adverse effects. Although the American College of Rheumatology has recommended that aerobic exercise be included in OA treatment plans[2], arthritis and its associated joint pain and stiffness act as significant barriers for those attempting to perform land-based weight-bearing activities[3,4]. Additionally, the idea that increased physical activity may result in greater wear and tear on already-affected joints remains a substantial concern for patients[5,6]. In this context, swimming appears to be the ideal form of aerobic exercise for middle-aged and older patients with OA. The minimal weight-bearing stress facilitated by the buoyancy effects of water is an important element for patients with OA who exhibit orthopedic hip and knee problems. Additionally, many patients with OA are obese, and obese patients are known to experience heat-related problems when exercising in a hot environment[7]. Swimming is characterized by a reduced heat load when participants are surrounded by water[8,9,10].

Because of these excellent traits of water-based exercise, swimming has been widely recommended for the treatment of OA. Surprisingly, however, no study to date has been conducted to investigate the efficacy of swimming exercise training in patients with OA. Thus, there is an urgent need to conduct randomized clinical trials to determine whether swimming exercise is truly beneficial to patients with OA.

Accordingly, the primary aim of our present study was to determine the effects of swimming exercise training interventions on primary symptoms of OA (joint pain, stiffness, and physical limitation) and functional capacity in

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middle-aged and older patients with OA. Additionally, the effect on quality of life was also addressed as a secondary aim of the study. We included cycling training as a comparison group because it is a land-based non–weight-bearing exercise that has been shown to be effective in alleviating pain and improving function in patients with OA[11,12]. Our working hypothesis was that swimming exercise would produce reductions in joint pain and stiffness and improvements in functional capacity in patients with OA.

MATERIALS AND METHODS

Patients. Sedentary middle-aged and older adults (n = 48) with Kellgren-Lawrence grade I-III radiographic OA were studied (Table 1). Participants were recruited from orthopedic clinics and senior citizens' centers in the local community through flyers, e-mails, and information sharing and were screened for study participation. All power calculations were performed using nQuery Adviser computer software. Sample size calculations were based on the number of subjects needed to detect significant changes in primary dependent variables [e.g., Western Ontario and McMaster Universities Arthritis Index (WOMAC) pain and stiffness scales, isokinetic muscle strength] from baseline levels in response to exercise training. The estimated effect sizes for each dependent variable were based on previous exercise studies in mainly middle-aged and older men and women. The magnitude of these changes translates into effect sizes of 0.82 to 1.0. Therefore, with our estimate of 20 subjects/group, we should have > 80% power to detect the changes in each group. Exclusion criteria were (1) having engaged in strenuous physical activity more than twice per week for the previous year, (2) unstable cardiac or pulmonary diseases, (3) joint replacement surgery during the past year, (4) intraarticular injection or systemic corticosteroid usage within the past 6 months, (5) severe disabling comorbidity that would disallow receiving exercise therapy, and (6) aquaphobia. The majority of the subjects were white (~70%) and had OA in lower limbs (~90%; Table 1). The Institutional Review Board at the University of Texas at Austin reviewed and approved the study. All volunteers gave their written informed consent before participation.

Exercise training intervention. Following baseline measurements, participants were randomly assigned by a blinded investigator to either swimming (n = 24) or cycling (n = 24) exercise training groups according to sequentially numbered, sealed, opaque envelopes indicating treatment allocation (Figure 1). Supervised exercise training conformed to guidelines established by the American College of Sports Medicine[13]. For the first few weeks of the supervised exercise training, participants received active coaching and instruction by a member of the research team. Initially, participants exercised for 20–30 min/day, 3 days/week at an exercise intensity of 40-50% of heart rate reserve (HRR). HRR was calculated using this equation: (maximal heart rate – resting heart rate) + resting heart rate[14] and was monitored daily. As each participant's level of fitness improved, the intensity and duration of exercise increased with the goal of attaining 40-45 min/day, 3 days/week at an intensity of 60-70% of HRR. Exercise training lasted 12 weeks. During the course of the investigation, participants were instructed to maintain their usual lifestyle and dietary habits.

Table 1. Participant demographic and clinical characteristics.

Variable	Cycling	Swimming
Race and ethnicity, n		
White	18	16
African American	3	4
Hispanic	3	3
Asian	0	0
Other	0	1
Affected joints, n		
Foot	2	2
Hand	2	1
Hip	3	2
Knee	15	18
Shoulder	1	0
Spine	1	0

The swimming training was performed in the swimming pools (25-yard length) located in Gregory Gymnasium on The University of Texas at Austin campus. Water temperature of the swimming pool was held constant at 27–28°C. All the swimming sessions were supervised by an investigator who was certified as a Red Cross Water Safety and Red Cross Lifeguard instructor. Subjects used freestyle, breast stroke, or a combination. One subject had no previous swimming experience. For this subject, one-on-one learn-to-swim coaching was combined with swimming with a kick board and fins to maintain the heart rate within the prescribed zone. The cycling training was performed on a stationary cycle ergometer in the Exercise Training Intervention Core Laboratory on The University of Texas at Austin campus and was supervised by an investigator who was a certified personal trainer. Each participant received instructions to exercise continuously except during the time needed for checking a target heart rate by heart rate monitor (Polar Electro) secured on each participant's chest. Heart rate monitors were waterproof and suitable for both cycling and swimming exercises.

Testing sessions. At baseline and postintervention, measurements were performed in the same order and at the same time of day on each participant after the participant had refrained from alcohol and exercise for at least 12 h prior to arrival. All prescription and over-the-counter medicines and supplements were identical for 7 days prior to the pretesting and posttesting sessions. To avoid the acute effect of exercise, participants were studied at least 48 h after their last exercise training session for the postintervention testing session. In an attempt to minimize the "learning effects" or "training effects" involved in repeated tests, familiarization sessions were conducted prior to the start of the exercise intervention. Prior to the pretesting, each subject was fully familiarized with the measurements and performed repeated trial runs. Investigators were blinded to the group assignment.

Body mass and composition. Height and body mass were measured with a physicians' balance scale (Seca) while the participants were barefoot and in light clothing. Body mass index was calculated using the equation body mass (kg)/height squared (m^2). Body fat percentage, lean tissue mass, and visceral adipose tissue were determined noninvasively using dual-energy x-ray absorptiometry (GE Lunar Radiation)[15].

Physical activity. Measurements of physical activity were performed using the Godin physical activity questionnaire[16].

Physical performance. Physical performance was determined with the 6-min walk test[17]. Participants received instructions to walk as far as possible in 6 min on a flat, indoor surface and did not receive feedback or encouragement during the test but were allowed to rest if needed. Footwear was recorded at the baseline testing session and replicated post intervention. Additionally, during each testing visit the participant was equipped with a pedometer (Omron HJ-324U) to assess the number of steps and stride lengths[18].

Muscle strength and power. To determine upper body muscular strength, maximal isometric grip strength of both arms was assessed unilaterally using a standard grip strength dynamometer. To determine lower body muscular strength, isokinetic knee flexor and extensor strengths of both legs were assessed unilaterally at an angular velocity of 60°/s and 120°/s[19] using an isokinetic dynamometer (Biodex Medical Systems), which was calibrated before every testing session. The pelvis, trunk, and thighs were stabilized with straps. Participants were asked to cross their arms on their chest during testing and perform 3 submaximal practice repetitions. This was followed by 5 maximal repetitions of flexion and extension in both legs, and no encouragement was provided. The peak torque reported was the average of the highest right and left scores of the 5 maximal efforts. The reliability values ranged from 0.88-0.97.

Pain and disease severity. Physical function, stiffness, and pain were

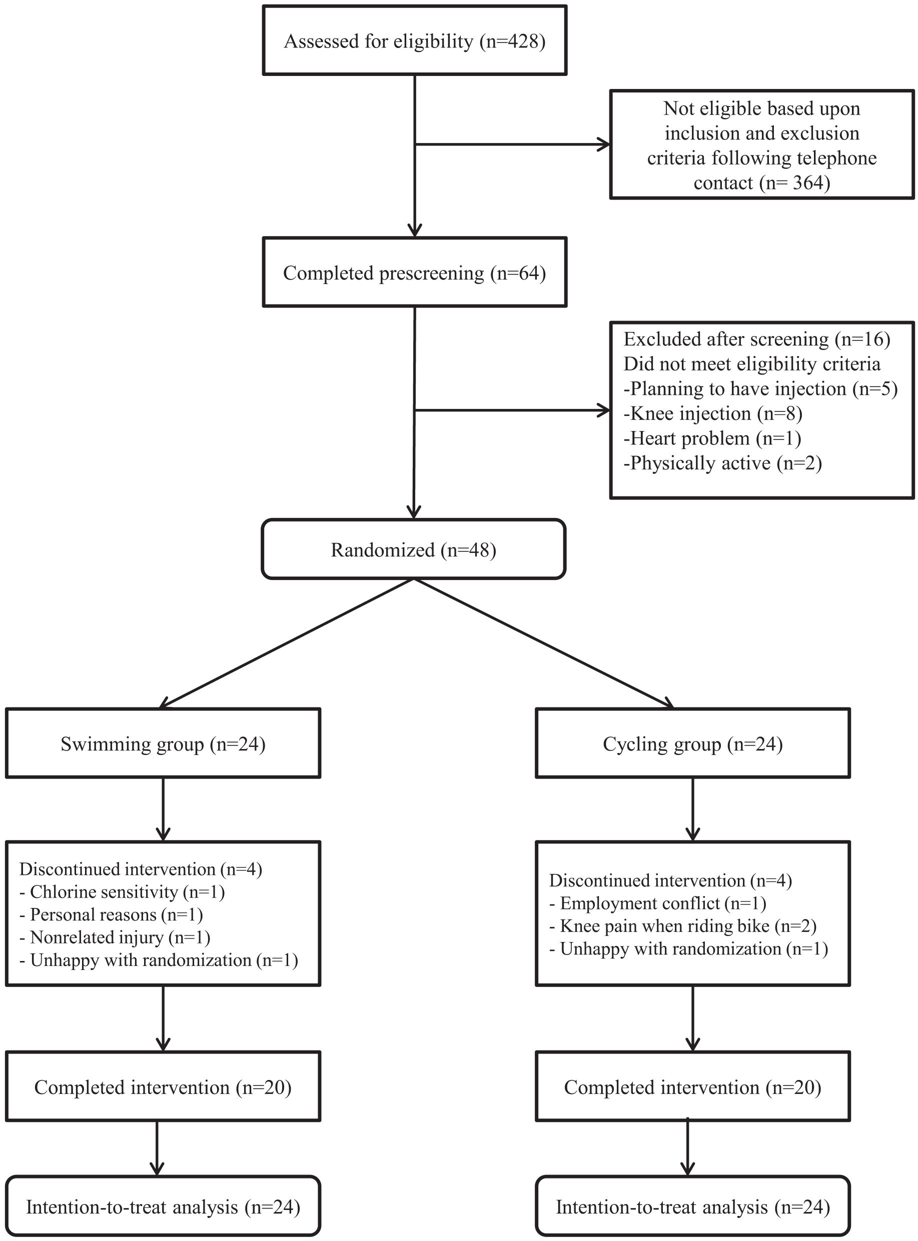

Figure 1. Participant flow through the trial.

evaluated using the WOMAC Index, a self-administered questionnaire. The WOMAC has been widely used in the evaluation of OA and consists of 24 items on a 5-point Likert scale (0 = none, 1 = mild, 2 = moderate, 3 = severe, 4 = extreme) that deal with participant's perception of pain, joint stiffness, and physical function[20].

Life quality. Health-related quality of life (HRQOL) was assessed with a validated self-report questionnaire, the Medical Outcomes Study Short Form-36 (SF-36; Medical Outcomes Trust), which consists of 36 questions that evaluate physical and mental HRQOL[21].

Statistical analyses. Chi-squared test was used to analyze categorical variables, and continuous baseline variables were analyzed using an independent sample t test or the Mann-Whitney U test, based on the results from a Shapiro–Wilk test of normality. Data were analyzed using an intent-to-treat analysis with a longitudinal modeling with random effects for all 48 randomized participants[22]. The longitudinal modeling allows all observed repeated measures to be included in the analyses and may be suited for exercise intervention trials[22]. We also determined that the subjects who dropped out of the exercise training program were not systematically different from those who remained and completed the program. To ensure the validity of the intention-to-treat analysis, we also conducted a per-protocol analysis of the 40 participants who completed the exercise intervention[23]. Intention-to-treat analysis of 48 participants, including 8 dropouts, was consistent with the per-protocol analysis of the 40 participants who completed the exercise interventions. Accordingly, we have reported results only from the intention-to-treat analysis. A 2-way (time × group) repeated measures ANOVA was performed to compare outcomes of interest, with statistical significance set at an α-level of 0.05. When a significant main effect of time, treatment, or treatment × time interaction was detected, paired samples t tests were used to assess intragroup differences at baseline and later.

Because our present study was not adequately powered to detect significant group differences, changes in key dependent variables with each exercise training were emphasized. All statistical analyses, including the imputation of missing values, were performed with SPSS Version 22.0 software (SPSS Inc.). Data are presented as mean ± SEM.

RESULTS

Selected participant demographic and clinical characteristics at baseline are presented in Table 1. Cycling and swimming groups were not different in age (61 ± 1 vs 59 ± 2 yrs), race, ethnicity, sex distribution (2 men and 22 women in both groups), education (16 ± 1 vs 16 ± 1 yr), and OA-affected joints. Among the 48 participants randomly assigned to the groups, 4 participants in each group dropped out prior to the end of the intervention (mostly owing to a lack of time, job conflict, etc.). The remaining participants had excellent attendance and adherence to swimming (98%) and cycling (97%) exercise training.

At baseline, there were no significant differences in physical characteristics and body stature between participants in the swimming and cycling exercise groups (Table 2). After the 12-week exercise intervention, body mass, visceral adiposity, and waist and hip circumference were decreased in both exercise training groups (all $p < 0.01$). There were no significant differences in the magnitude of the reductions between the 2 training groups ($p = 0.13$).

As shown in Table 3, there were reductions in joint pain, stiffness, and functional limitation, as determined by the WOMAC index, in both exercise groups (all $p < 0.001$). Participants in both swimming and cycling exercise training groups demonstrated significant increases in distance covered during the 6-min walk test ($p < 0.001$; Table 4). Maximal grip strength and isokinetic knee extensor and flexor strength increased in both swimming and cycling exercise training groups (all $p < 0.05$; Table 4 and Figure 2).

DISCUSSION

Our present study is the first, to our knowledge, to demonstrate the benefit of swimming exercise training for treatment of OA. Swimming has been recommended widely and consistently by various medical organizations for the management of OA[2,24,25], but the efficacy of swimming in patients with OA has never been studied. We found that 3 months of swimming exercise training produced substantial reductions in joint pain (~40%), stiffness (~30%), and functional limitation (~25%) in patients with OA. Additionally, these changes were accompanied by the improvements in physical performance, upper and lower body muscle strength, as well as reductions in body mass, and joint stiffness. In general, the benefits gained from the water-based exercise were similar to the land-based control modality of cycling, so that the benefits for this population are well established[11,12].

Joint pain and stiffness are the most common symptoms in patients with OA and are the primary barriers for performing activities of daily living in this patient population[3]. The present results demonstrate that non–weight-bearing exercise performed in water led to ~40% reductions in joint pain that patients with OA experience while performing daily activities on land. Additionally, regular swimming produced ~30% reductions in joint stiffness and ~25% decrease in functional limitation. The magnitude of these reductions in WOMAC scores exceeds minimal clinically important improvement threshold either expressed as 17% difference[26] or 0.51 to 1.33 points[27].

Most patients with OA spend most of their time on land performing the activities of daily living. Because of the principle of the specificity of exercise training[28], it was not known whether the functional benefits gained in water would be translated into better physical function in normal daily life on land. In our present study, we assessed muscular strength, as determined by isokinetic quadriceps and hamstring strength, and handgrip strength. All the muscle strength measures improved significantly after the swimming intervention. Additionally, physical performance, as determined by the 6-min walk distance, improved significantly by 6% and 8% in the cycling and swimming groups, respectively. Importantly, improvements in muscular strength and physical function achieved by swimming were similar to those elicited by cycling exercises performed on land.

Although there were no significant differences between

Table 2. Changes in selected participant characteristics. Values are mean ± SEM.

Variables	Cycling		Swimming	
	Baseline	After	Baseline	After
Body mass, kg	84.5 ± 3.8	83.0 ± 4.1*	92.0 ± 4.7	89.4 ± 3.9*
Body mass index, kg/m^2	31.6 ± 1.7	31.0 ± 1.9	34.6 ± 2.1	33.9 ± 1.7
Waist circumference, cm	102 ± 4	99 ± 4*	106 ± 3	103 ± 3*
Hip circumference, cm	116 ± 3	114 ± 3*	120 ± 3	117 ± 3*
Body fat, %	44 ± 2	44 ± 2	45 ± 2	44 ± 2
Lean tissue mass, kg	96 ± 4	97 ± 4	102 ± 3	101 ± 3
Visceral adipose tissue, kg	3.3 ± 0.4	3.2 ± 0.4*	3.4 ± 0.3	3.0 ± 0.3*
Godin physical activity score, U	15 ± 2	35 ± 1*	13 ± 1	38 ± 2*

* $p < 0.05$ versus baseline.

Table 3. Changes in physical function, pain, and health-related quality of life. Values are mean ± SEM.

Variables	Cycling		Swimming	
	Baseline	After	Baseline	After
WOMAC				
Pain (0–20)	7.8 ± 0.9	4.5 ± 0.5*	6.9 ± 0.7	4.2 ± 0.5*
Stiffness (0–8)	4.4 ± 0.4	3.1 ± 0.3*	3.8 ± 0.3	2.6 ± 0.3*
Functional limitation (0–68)	23.5 ± 1.8	17.5 ± 2.7*	20.9 ± 2.1	11.7 ± 1.9*
Health-related quality of life (SF-36)				
Mental score (0–100)	64 ± 4	78 ± 3*	65 ± 3	79 ± 3*
Physical score (0–100)	51 ± 4	69 ± 3*	53 ± 4	73 ± 3*

* $p < 0.05$ versus baseline. WOMAC: Western Ontario and McMaster University Osteoarthritis Index; SF-36: Medical Outcomes Study Short Form-36.

Table 4. Changes in physical function and muscle strength tests.

Variables	Cycling		Swimming	
	Baseline	After	Baseline	After
Six-min walk test, m	552 ± 22	594 ± 19*	556 ± 21	589 ± 22*
Six-min walk test, steps	775 ± 12	879 ± 13*	782 ± 18	890 ± 16*
Walk speed, m/s	1.5 ± 0.06	1.7 ± 0.06*	1.5 ± 0.06	1.6 ± 0.1*
Grip strength left, kg	21.8 ± 1	23.0 ± 1*	20.6 ± 1	21.3 ± 1*
Grip strength right, kg	22.8 ± 1	24.6 ± 1*	20.2 ± 1	20.6 ± 1*
Isokinetic knee peak torque at 60°/s				
Right-extension, Nm	62 ± 5	72 ± 5*	58 ± 4	68 ± 4*
Right-flexion, Nm	41 ± 4	50 ± 3*	42 ± 3	50 ± 3*
Left-extension, Nm	58 ± 4	64 ± 4*	60 ± 3	69 ± 4*
Left-flexion, Nm	41 ± 5	50 ± 3*	42 ± 3	50 ± 3*
Isokinetic knee peak torque at 120°/s				
Right-extension, Nm	46 ± 4	55 ± 4*	40 ± 3	48 ± 3*
Right-flexion, Nm	35 ± 3	41 ± 3*	32 ± 2	40 ± 2*
Left-extension, Nm	44 ± 3	53 ± 3*	44 ± 2	56 ± 3*
Left-flexion, Nm	35 ± 3	40 ± 3*	33 ± 2	44 ± 2*

Values are mean ± SEM. * $p < 0.05$ versus baseline.

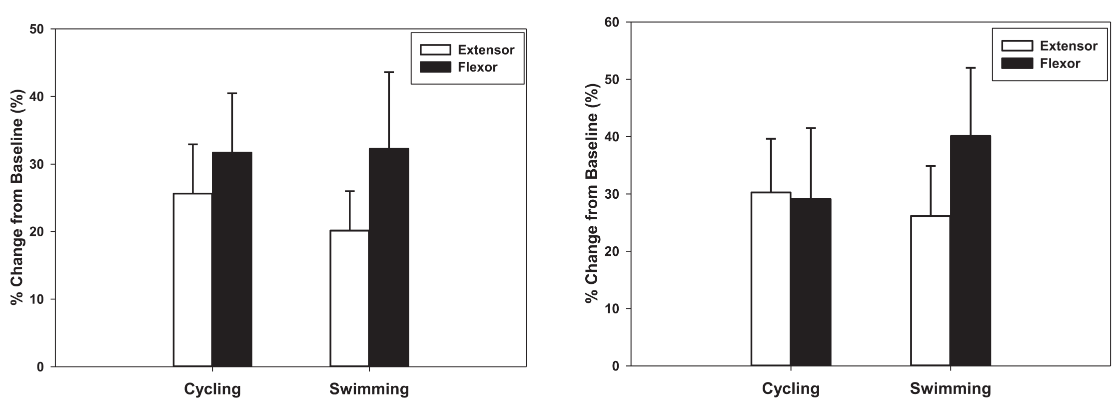

Figure 2. Relative percent increases in isokinetic knee extensor and flexor peak torque at an angular velocity of 60°/s (left panel) and 120°/s (right panel; average of right and left legs). Values are mean ± SEM. All $p < 0.05$.

swimming and cycling exercise training groups, this does not diminish the clinical importance of our study — it enhances it. A number of studies have shown a benefit of land-based exercise intervention compared with sedentary control conditions in patients with OA[29,30]. While we considered adding a sedentary (non-exercising) control condition, we determined it to be unethical to forgo an effective treatment for patients with OA. We are aware that some studies have used a waiting list–type sedentary control prior to entrance into the study[31,32], but we decided against implementing it, because the integrity of a truly randomized study design, one of the most important aspects of any clinical trial, would have been lost with such a study design. Thus, we decided to use cycling as a land-based non–weight-bearing exercise training comparison group because it has been shown to be effective in reducing pain, but more importantly is well-tolerated in patients with OA[11,12].

Our present study was the first, to our knowledge, to investigate the effects of swimming exercise in patients with OA. However, several studies have compared aquatic exercises (e.g., water aerobics) to land-based exercises[9,33]. These studies found that both land-based and aquatic exercises reduced pain and improved physical function in patients with OA. Although land-based exercise might be more convenient to perform, there may be psychological barriers, because patients with OA have enormous difficulty performing weight-bearing physical activity in their daily life owing to joint pain, joint stiffness, and muscle weakness[34,35] that could be aggravated by exercises, leading them to a sedentary lifestyle[3] or to limit their daily physical activity to the minimum[4]. In light of this, water-based exercises would be an ideal form of physical activity for patients with OA because of the minimal weight-bearing stress, humid environment, and reduced heat load[8,9]. Although swimming and aquatic exercise take place in water and are well received by patients with OA, these water-based exercises differ significantly in regard to body position, muscle groups used, and sustainable exercise intensity. Yet they are often categorized into the same exercise mode, although the land-based counterparts of aerobic dancing and jogging/running are hardly clustered together. Further studies are needed to compare swimming and aquatic exercise or to investigate the effect of the combination of swimming and aquatic exercise in treatment of OA.

There were several limitations to our study. Participants performed supervised exercise for only 3 months in this time span. Although we observed health benefits of exercise training in this time, it is unknown whether continued participation in exercise training would maintain or enhance these benefits. An additional limitation is the lack of participant blinding to treatment allocation. Swimming is considered an ideal form of exercise for patients with OA. Placement in the alternate exercise condition may have affected self-reported outcomes or motivation. This is, however, unlikely because the number of dropouts were equal between exercise interventions. Lastly, we included only patients with mild to moderate radiographic OA. Not included were patients with advanced stages of OA who were using a walker or awaiting a joint replacement. Thus, we cannot generalize the present findings to that population. Future studies should investigate the benefits of exercise training in these patients; they would likely benefit from a swimming or cycling exercise program.

Our results indicated that 3 months of non–weight-bearing exercise training, including swimming and cycling, reduced joint pain, stiffness, and functional limitation and improved physical performance and functional capacity in patients with OA. Not only are these the first findings, to our knowledge, to indicate the efficacy of swimming exercise for patients with OA, but they also demonstrate that swimming exercise exerts functional benefits similar to the more frequently prescribed land-based cycling training. Future studies should investigate whether other benefits of swimming exercise (i.e., improved cardiovascular outcomes) are present after swimming exercise training in patients with OA.

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