Aquatic Physical Therapy for Hip and Knee Osteoarthritis: Results of a Single-Blind Randomized Controlled Trial

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Background and Purpose

Aquatic physical therapy is frequently used in the management of patients with hip and knee osteoarthritis (OA), yet there is little research establishing its efficacy for this population. The purpose of this study was to evaluate the effects of aquatic physical therapy on hip or knee OA.

Subjects

A total of 71 volunteers with symptomatic hip OA or knee OA participated in this study.

Methods

The study was designed as a randomized controlled trial in which participants randomly received 6 weeks of aquatic physical therapy or no aquatic physical therapy. Outcome measures included pain, physical function, physical activity levels, quality of life, and muscle strength.

Results

The intervention resulted in less pain and joint stiffness and greater physical function, quality of life, and hip muscle strength. Totals of 72% and 75% of participants reported improvements in pain and function, respectively, compared with only 17% (each) of control participants. Benefits were maintained 6 weeks after the completion of physical therapy, with 84% of participants continuing independently.

Discussion and Conclusion

Compared with no intervention, a 6-week program of aquatic physical therapy resulted in significantly less pain and improved physical function, strength, and quality of life. It is unclear whether the benefits were attributable to intervention effects or a placebo response.

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Osteoarthritis (OA) is one of the most prevalent musculoskeletal conditions affecting the elderly population worldwide,[1] and its prevalence is predicted to rise significantly in the future as the population ages.[2] Knee OA currently affects about 40% of people aged over 75 years, and hip OA affects about 10%.[3] People with OA frequently report joint pain, stiffness, loss of physical function, increasing immobility, and muscle weakness. Such signs and symptoms of the disease often culminate in reductions in quality of life. Contemporary management of OA aims to alleviate pain and disability while avoiding adverse effects of therapy.[4] Current guidelines recommend nonpharmacologic methods, such as physical therapy, as first-line options in the management of OA.[5] Physical therapy for OA may be provided on land or in an aquatic environment.

"Hydrotherapy" is a term encompassing a range of therapeutic and exercise activities carried out in heated pools by a variety of providers. Experts rate hydrotherapy as one of the least toxic of 33 potential treatments for knee OA.[6] Aquatic physical therapy incorporates individual assessment, evidence-based practice, and clinical reasoning skills to devise treatment plans based on the principles of hydrostatics and hydrodynamics and the physiologic effects of immersion.[7] Aquatic physical therapy offers several benefits over land-based physical therapy for people with OA. Buoyancy reduces loading across joints affected by pain and allows the performance of functional closed-chain exercises that otherwise may be too difficult on land. Water turbulence can be used as a method of increasing resistance, and percentage of body weight borne across the lower limbs can be decreased or progressed in proportion to the depth of immersion.[8,9] The warmth and pressure of the water may further assist with pain relief, swelling reduction, and ease of movement.

Despite the widespread provision of aquatic physical therapy for people with hip or knee OA, there is little evidence attesting to its efficacy in this population. Although many studies have reported positive effects of hydrotherapy interventions in cohorts with various arthritic conditions,[10] few have evaluated a sample selected on the basis of knee or hip OA alone. A recent study found no significant benefit of hydrotherapy over a gym-based program or no intervention for symptoms in people with hip or knee OA.[11] However, the program tested by the authors made use of nonfunctional body positions and had a limited capacity for progression, features that may explain their nonsignificant findings. Methodological limitations in other published studies on OA include inadequate sample size, nonrandom allocation, and no intention-to-treat analysis.[12–15] Furthermore, most hydrotherapy programs demonstrate little consideration of hydrostatic or hydrodynamic principles in their choice of exercises, thus reducing the potential for benefit from the overall program. The present study was designed to address the limitations of previous studies through the use of an adequately powered randomized controlled trial with intention-to-treat analysis and a functional progressive intervention that maximized the unique properties of water to optimize outcomes.

The aim of this study was to test the efficacy of a 6-week aquatic physical therapy program in a group of people with symptomatic hip OA, knee OA, or both. The primary hypothesis was that aquatic physical therapy would result in greater improvements in pain and physical function than would no aquatic physical therapy. The secondary hypothesis was that aquatic physical therapy would result in greater improvements in stiffness, quality of life, physical activity, and muscle strength. Finally, we aimed to determine whether participants were adherent to ongoing independent aquatic physical therapy once the program had ceased and whether any benefits of the program remained 6 weeks later.

Method

Participants

Diagnosis was based on American College of Rheumatology classification criteria.[16,17] Volunteers aged 50 years and older and with hip OA or knee OA were recruited by advertisements in local clubs, libraries, general practitioner's rooms, print and radio media, and the orthopedic clinic at a metropolitan hospital. Participants with knee OA were included if they had knee pain on most days of the previous month and osteophytes on radiographs. Participants with hip OA were included if they had hip pain and osteophytes and joint space narrowing on radiographs. Other inclusion criteria for all participants were an average severity of pain of greater than 3 cm on a 10-cm visual analog scale (VAS) and difficulty with stair climbing, walking, or getting in or out of a chair. Exclusion criteria included contraindications to aquatic physical therapy[7]; significant back or other joint pain; recent (preceding 6 months) joint injections, surgery, physical therapy, or hydrotherapy; lower-limb joint replacement; inability to understand English; and inability to safely enter and exit the pool.

Between October 2003 and April 2004, 312 volunteers were screened. Of these volunteers, 71 fulfilled the selection criteria and were enrolled in the study. Thirty-six participants were randomly assigned to an aquatic physical therapy group (intervention group), and 35 participants were randomly assigned to a control group. One aquatic physical therapy participant withdrew after

randomization, did not undergo the intervention as allocated, and did not return for reassessment. Four control participants withdrew prior to reassessment; however, 2 of them completed reassessment questionnaires only. All participants provided written informed consent.

Protocol

The trial comprised a 6-week intervention period (Fig. 1). Participants were assessed immediately before treatment (0 weeks) and immediately after treatment was completed (6 weeks). Furthermore, the aquatic physical therapy group underwent follow-up assessment at 12 weeks (ie, 6 weeks after the intervention was completed) to determine whether any benefits of the intervention were maintained in the short term and to assess adherence to independent aquatic physical therapy. Every effort was made to obtain reassessment data on primary outcomes from any participant who withdrew from the study.

Assignment

Following the baseline assessment, participants were randomly assigned to either the aquatic physical therapy group or the control group. Block randomization (randomly alternating blocks of 4 and 6) stratified for sex was set up with a computer-generated table of random numbers. Assignment was concealed in sequential opaque envelopes and was revealed by an independent researcher not involved in eligibility assessment, outcome assessment, or intervention following the baseline assessment.

Aquatic Physical Therapy Intervention

The aquatic physical therapy program comprised functional weight-bearing and progressive exercises (Tab. 1) provided twice weekly (45–60 minutes each) for 6 weeks. An experienced aquatic physical therapist individually instructed participants in the hydrotherapy pool (water temperature = 34°C), with a maximum of 6 participants per session. Quality of movement was emphasized, and the therapist palpated the lower-limb musculature to ensure appropriate contraction throughout the exercises. Balance without the aid of rails to maximize postural and isometric leg stance control was achieved with all participants. A neutral spinal position also was taught; feedback was provided on posture, transversus abdominis muscle contraction, and trunk control. Individual progression to subsequent phases of the program was clinically determined by the therapist and occurred upon completion of the prior phase with either no or minimal symptom exacerbation. Attendance at intervention sessions and adverse effects of the intervention were recorded by the aquatic physical therapist.

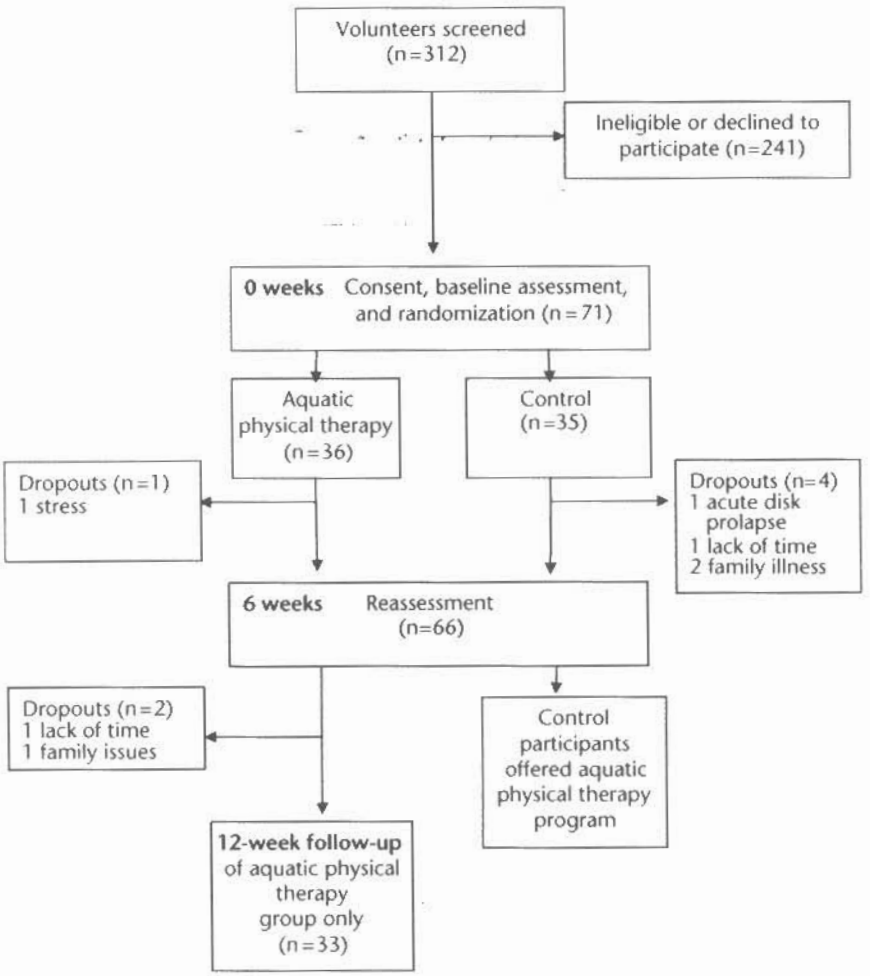

Figure 1.
Flow of participants through the trial.

Upon completion of the 6-week program, participants were encouraged to continue independent aquatic physical therapy twice weekly at a local pool and were provided with details of local pools and a written description of the exercises to maximize adherence. During the follow-up period, between week 6 and week 12, participants recorded in a logbook the sessions of independent aquatic physical therapy that they undertook. Participants continued with their usual med-

Table 1.
Aquatic Physical Therapy Program[a]

Phase	Water Depth	Lower-Limb Exercises	Sets and Repetitions (Each Leg)	Walking
1	Xiphisternum (28%–35% WB)[8]	1. Double-leg squats 2. Double-leg calf raises 3. Dynamic lunge	2×10 2×10 2×10	6 min
2	ASIS (47%–54% WB)[8]	As for phase 1	As for phase 1	8 min
3	ASIS	As for phase 1, plus: 4. Single-leg stance, contralateral knee flexion/extension 5. Single-leg stance, contralateral hip abduction/adduction 6. Single-leg stance, contralateral hip hitching	 2×10 2×10 2×10	10 min
4	ASIS	1. Single-leg squats 2. Single-leg calf raises 3. Dynamic lunge Plus exercises 4, 5, and 6 from phase 3	2×10 2×10 2×10	10 min
5	ASIS	As for phase 4, plus: 7. Step-ups	 2×10	10 min
6	ASIS	As for phase 5, but modify: 7. Step-downs	 2×10	10 min
7	ASIS	As for phase 6, but for exercises 4 and 5, increase speed (resistance) of moving leg as able	2×10 followed by 1×5	10 min
8	ASIS	As for phase 7	3×10	10 min
9	ASIS	As for phase 7	3×10 followed by 1×5	10 min
10	ASIS	As for phase 7	4×10	10 min
11	ASIS	As for phase 7	4×10 followed by 1×5	10 min
12	ASIS	As for phase 7	5×10	10 min

[a] Each session incorporated a warm-up and a cool-down (2 widths of the pool walking forward, backward, and sideways and high stepping) conducted at the depths indicated. Walking immediately followed the completion of lower-limb exercises. All single-leg exercises were performed with both the left and the right legs. The step height was 145 mm. ASIS=anterior superior iliac spine, WB=weight bearing.

ication regimen over the entire 12-week period.

Control Group

The control group did not receive any aquatic physical therapy over the 6-week trial; however, these participants were offered the intervention following the 6-week assessment to minimize dropouts from this group. Thus, these participants did not complete a 12-week assessment. Participants were instructed to continue with their usual daily activities and medication regimen and not to commence any new exercise programs or treatments for their OA-affected joints.

Masking

An examiner who was unaware of group assignment performed all outcome assessments. The statistician was unaware of treatment allocation until completion of the statistical analyses.

Primary Outcomes

Pain on movement (over the preceding week) in the primary OA joint was measured with a VAS numbered in 1-cm intervals. Previous research indicated that such a scale is a valid, reliable, and responsive technique for assessing pain in subjects with OA when completed by those subjects.[18,19] Subject-perceived global changes (since trial commencement) in pain and physical function were recorded on 5-point Likert scales ranging from 1 (much worse) to 5 (much better). Participants who scored their global changes as 4 or 5 were classified as showing improvement, and those scoring their changes as 1, 2, or

3 were classified as not showing improvement.

Secondary Outcomes

Questionnaires. The 24-item disease-specific Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) was used to assess pain, stiffness, and physical function in the primary OA joint over the previous 48 hours. This measure has been validated with respect to reliability, face validity, content validity, construct validity, and responsiveness for people with OA of the hip or knee.[20] Health-related quality of life over the previous week was assessed with the 15-item Assessment of Quality of Life scale.[21] This scale has been validated for use in the general population. Physical activity levels over the previous week were assessed with the Physical Activity Scale for the Elderly (PASE) (with supervised aquatic physical therapy sessions excluded from the analyses to accurately measure independent activity). The PASE demonstrated good test-retest reliability, convergent validity, and construct validity in older adults with knee pain.[22]

Muscle strength. Isometric hip abduction and knee extension strength (force-generating capacity) was assessed bilaterally with a Nicholas Manual Muscle Tester (model 01160)* according to the protocol of Bohannon.[23] The hip abductors were chosen because some data have suggested that stronger hip abductors may assist in reducing the knee adduction moment.[24] The quadriceps femoris muscles were assessed because knee extensor strength has been correlated with both pain severity and physical function in knee OA.[25–27] The peak strength of each muscle group was assessed 3 times, and the highest score was recorded (in kilograms). Handheld dynamometry demonstrated adequate test-retest reliability for the muscles of the lower limbs in a community-dwelling group of older people (intraclass correlation coefficients [ICCs] = .95–1.00).[28]

Balance. Dynamic standing balance was assessed with the step test, a reliable and valid measure in older people (ICC > .9)[29] that is sensitive enough to discriminate between those with knee OA and those without knee OA.[30] Participants stood barefoot on the osteoarthritic limb in front of a 7.5-cm step and were instructed to move the opposite foot on and off the step as many times as possible over 15 seconds. This test does not require the participant to move body weight over the step but simply to perform a potentially destabilizing foot placement activity. The number of times the participant could place the foot on the step and return it to the floor was recorded, with higher scores indicating better balance.

Physical function. The Timed "Up & Go" Test was used to assess functional ability.[31] This test demonstrated good intratester and intertester reliability (ICC = .99) for a geriatric population as well as criterion validity. Participants were instructed to rise from a standard armchair, walk to a point on the floor 3 m away, return to the chair, and sit down again while being timed with a stopwatch. Participants performed the test only once and at their own pace.

Gait. The Six-Minute Walk Test was used to evaluate how far participants could walk at a fast, comfortable pace. This test was validated as a measure of physical function in people with heart failure and respiratory disease.[32] Participants walked back and forth over a 50-m stretch of carpeted corridor for 6 minutes, and the total distance walked was recorded (in meters).

Sample Size

A pain reduction of 1.75 cm on a VAS is recommended as the minimum clinically important difference to be detected in OA trials.[33] With 58 participants, the study had 90% power to detect a difference in pain reduction of 1.75 cm between groups, assuming a standard deviation of 2.0 cm and a significance level of 5%. Numbers were increased to 71 participants to allow for dropouts.

Data Analyses

Data analyses were performed with SPSS software† and an alpha level of .05 on an intention-to-treat basis. The last observation carried forward was used to impute data missing at reassessment; a score of 3 ("unchanged") was allocated for missing global change measures. Data were checked for normality and homogeneity of variance prior to analyses. Baseline comparability between groups was determined with independent *t* tests (because most data were normally distributed) or chi-square tests. Mean scores at 6 weeks were compared between groups by use of univariate analysis of variance; baseline scores were included as covariates to control for any group differences at baseline. Effect sizes were calculated; effect sizes of .2 were regarded as small, those of .5 were regarded as medium, and those of .8 were regarded as large. A comparison of the numbers of participants showing improvement between groups was made with chi-square tests, and odds ratios (OR) (with 95% confidence intervals [CI]) were calculated. Outcomes at 6 and 12 weeks in the intervention group were compared by use of paired *t* tests.

Results

Groups were found not to be significantly different at baseline with regard to demographic characteris-

* Lafayette Instrument Co, 3700 Sagamore Pkwy North, PO Box 5729, Lafayette, IN 47903.

† SPSS Inc, 233 S Wacker Dr, Chicago, IL 60606.

Table 2.
Baseline Comparability of Participant Groups[a]

Parameter	Control Group (n=35)	Aquatic Physical Therapy Group (n=36)
Age, y	61.5 (7.8)	63.3 (9.5)
Height, m	1.61 (0.01)	1.63 (0.09)
Weight, kg	85 (17)	88 (15)
Body mass index, kg/m^2	32.9 (6.6)	33.8 (6.5)
Symptom duration, y	8.0 (10.6)	8.0 (9.3)
Sex, no. (%)	24 (69) female, 11 (31) male	24 (67) female, 12 (33) male
Symptomatic joint, no. (%)	24 (69) knee, 11 (31) hip	31 (86) knee, 5 (14) hip
Medications, no. (%)	16 (46) analgesics, 14 (40) NSAIDs, 14 (40) nutraceuticals[b]	20 (56) analgesics, 18 (50) NSAIDs, 14 (39) nutraceuticals
Primary outcomes		
VAS movement pain, 0–10 cm	5 (2)	6 (2)
Secondary outcomes		
WOMAC pain, 0–500 mm	199 (85)	202 (79)
WOMAC stiffness, 0–200 mm	100 (46)	99 (46)
WOMAC function, 0–1,700 mm	630 (315)	757 (327)
AQoL, −0.04 to 1.00	0.52 (0.20)	0.38 (0.17)[c]
PASE, 0–400	153 (79)	165 (80)
Hip abductor strength, kg		
Right	21.0 (7.2)	20.3 (8.2)
Left	22.3 (8.3)	20.6 (8.4)
Quadriceps femoris muscle strength, kg		
Right	24.5 (8.2)	26.6 (9.1)
Left	24.3 (8.3)	25.2 (9.3)
Timed "Up & Go" Test, s	10.38 (2.82)	11.26 (2.37)
Six-Minute Walk Test, m	448.09 (82.88)	420.56 (91.10)
Step test, no. of steps	13 (4)	13 (4)

[a] Data are presented as mean (SD) unless otherwise indicated. AQoL=Assessment of Quality of Life (with higher scores indicating better quality of life), NSAIDs=nonsteroidal anti-inflammatory drugs, PASE=Physical Activity Scale for the Elderly (with higher scores indicating greater physical activity), VAS=visual analog scale (with higher scores indicating more pain), WOMAC=Western Ontario and McMaster Universities Osteoarthritis Index (with higher scores indicating worse pain, stiffness, or physical function).
[b] *Nutraceutical* can be defined as a food (or part of a food) that provides medical or health benefits, including the prevention or treatment of a disease; typically glucosamine in this population.
[c] Significantly different from value for control group ($P<.01$).

tics or outcome measures (Tab. 2), with the exception of quality of life, which was significantly poorer in the aquatic physical therapy participants ($P<.01$).

Primary Outcomes

Aquatic physical therapy participants reported a mean reduction in pain on movement of 33% from baseline and thus demonstrated significantly less pain at 6 weeks than control participants ($P<.01$) (Tab. 3). This finding represented a small effect size (.24) for this outcome. Seventy-two percent (26 of 36) of the intervention participants reported a global improvement in pain; only 17% (6 of 35) of the control participants did so ($P<.001$) (Fig. 2). Similarly, 75% (27 of 36) of the intervention participants reported a global improvement in physical function; only 17% (6 of 31) of the control participants did so ($P<.001$) (Fig. 2). Aquatic physical therapy participants were more than

Table 3.
Outcome Scores at 6 Weeks Across Groups[a]

Outcome	$\bar{X}$ (SD)		*P*	Effect Size
	Control Group (n=35)	Aquatic Physical Therapy Group (n=36)		
Primary				
VAS movement pain, 0–10 cm	5 (2)	4 (2)	.003	.24
Secondary				
WOMAC pain, 0–500 mm	198 (108)	143 (79)	<.001	.28
WOMAC stiffness, 0–200 mm	95 (44)	73 (45)	.007	.24
WOMAC function, 0–1,700 mm	656 (373)	598 (316)	<.001	.08
AQoL, −0.04 to 1.00	0.50 (0.20)	0.43 (0.20)	.018	.17
PASE, 0–400	142 (77)	165 (70)	.351	.15
Hip abductor strength, kg				
Right	20.3 (6.8)	22.7 (8.3)	.012	.16
Left	21.0 (8.0)	22.2 (8.5)	.011	.07
Quadriceps femoris muscle strength, kg				
Right	24.7 (9.5)	29.9 (12.5)	.059	.23
Left	24.9 (10.3)	25.7 (10.6)	.193	.04
Timed "Up & Go" Test, s	10.30 (2.78)	10.32 (1.94)	.053	.00
Six-Minute Walk Test, m	440.38 (79.03)	441.72 (87.25)	.001	.01
Step test, no. of steps	14 (4)	13 (3)	.998	.14

[a] AQoL=Assessment of Quality of Life (with higher scores indicating better quality of life), PASE=Physical Activity Scale for the Elderly (with higher scores indicating greater physical activity), VAS=visual analog scale (with higher scores indicating more pain), WOMAC=Western Ontario and McMaster Universities Osteoarthritis Index (with higher scores indicating worse pain, stiffness, or physical function).

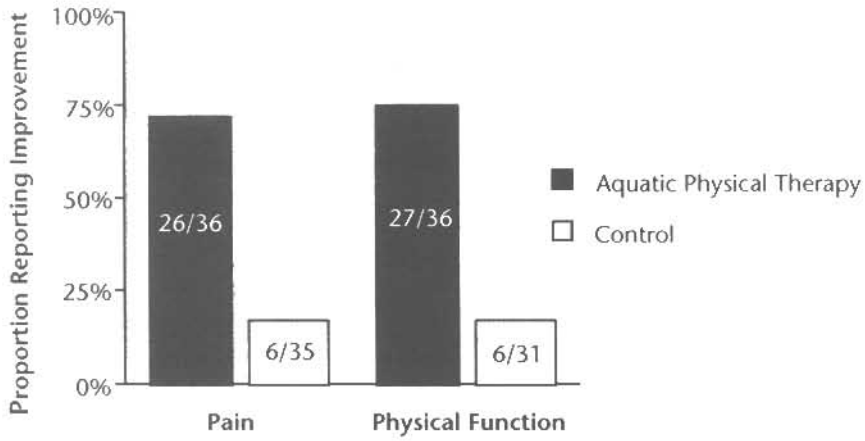

Figure 2.
Global improvement in pain and physical function at 6 weeks across groups.

12 times as likely as control participants to report global improvements in pain (OR=12.6, 95% CI=1.0–39.4), corresponding to a number needed to treat of 2 (95% CI=1–3), and physical function (OR=12.5, 95% CI=3.9–40.2), corresponding to a number needed to treat of 2 (95% CI=1–3).

Secondary Outcomes

The aquatic physical therapy participants reported significantly less pain and significantly superior physical function on many secondary outcomes (Tab. 3). Hip muscle strength and quality of life also were significantly greater in this group than in the control group at 6 weeks. Outcomes that were not significantly different following the intervention were quadriceps femoris muscle

Table 4.
Outcome Scores at Follow-up (12 Weeks) in the Aquatic Physical Therapy Group (n=36)[a]

Outcome	6 wk	12 wk	P
Primary			
VAS movement pain, 0–10 cm	4 (2)	4 (2)	.45
Secondary			
WOMAC pain, 0–500 mm	143 (79)	132 (89)	.23
WOMAC stiffness, 0–200 mm	73 (45)	65 (46)	.05
WOMAC function, 0–1,700 mm	598 (316)	556 (341)	.08
AQoL, −0.04 to 1.00	0.43 (0.20)	0.45 (0.22)	.31
PASE, 0–400[b]	140 (104)	160 (150)	.63
Hip abductor strength, kg			
Right	22.7 (8.3)	23.4 (10.7)	.44
Left	22.2 (8.5)	21.8 (8.8)	.46
Quadriceps femoris muscle strength, kg			
Right	29.9 (12.5)	29.2 (11.7)	.47
Left	25.7 (10.6)	24.5 (9.4)	.21
Timed "Up & Go" Test, s	10.32 (1.94)	9.98 (1.93)	.03
Six-Minute Walk Test, m	441.72 (87.25)	447.39 (89.07)	.18
Step test, no. of steps	13 (3)	14 (4)	.03

[a] Data are presented as mean (SD) unless otherwise indicated. AQoL=Assessment of Quality of Life (with higher scores indicating better quality of life), PASE=Physical Activity Scale for the Elderly (with higher scores indicating greater physical activity), VAS=visual analog scale (with higher scores indicating more pain), WOMAC=Western Ontario and McMaster Universities Osteoarthritis Index (with higher scores indicating worse pain, stiffness, or physical function).
[b] Data are presented as median (interquartile range) and were analyzed with the Wilcoxon signed rank test.

strength, the step test, the Timed "Up & Go" Test, and the PASE. Effect sizes for secondary outcomes were small at best.

Attendance and Adverse Effects

Only 2 participants failed to attend all 12 aquatic physical therapy sessions (excluding the participant who withdrew before attending any sessions); 1 of these 2 participants attended 10 sessions (83%), and the other participant attended 11 sessions (92%). Adverse effects were minor and did not affect ongoing participation. Seventeen (49%) participants reported mild joint discomfort, 3 (9%) reported mild lumbar pain, and 2 (6%) reported cramps in the calf or foot. Upon completion of the program, 11 participants (31%) had reached phase 12, and 1 (3%), 1 (3%), 1 (3%), 2 (5%), 10 (29%), and 9 (26%) had reached phases 6, 7, 8, 9, 10, and 11, respectively.

Ongoing Participation and Outcome at Follow-up in the Aquatic Physical Therapy Group

At follow-up, 84% of participants (28 of 33) had continued to undertake aquatic physical therapy independently since ceasing the supervised program. Over the 6-week follow-up period, 24% (8 of 33) attended the local pool less than once per week on average, 45% (15 of 33) attended 1 or 2 times per week, and 15% (5 of 33) attended 2 or 3 times per week; only 16% (5 of 33) failed to attend at all. Follow-up scores at 12 weeks for the aquatic physical therapy group were generally unchanged from scores obtained at 6 weeks (Tab. 4), suggesting that the benefits of the program were maintained in the short term.

Discussion

This randomized controlled trial evaluated the efficacy of aquatic physical therapy for hip OA and knee OA. Our findings demonstrated that a 6-week, twice-weekly program leads to reduced pain and joint stiffness as well as improved physical function, hip muscle strength, and quality of life in people with OA. Furthermore, the benefits of aquatic physical therapy appear to remain 6 weeks after the cessation of the supervised program. Despite statistically significant differences between groups, effect size calculations revealed only small benefits of aquatic physical therapy for pain, stiffness, right hip abductor strength, and quality of life and doubtful clin-

ical benefits for physical function and left hip abductor strength.

Few randomized controlled trials have evaluated hydrotherapy interventions in a sample selected on the basis of hip or knee OA alone.[11,12,14,15] Our findings of reduced pain and improved function with aquatic physical therapy concur with the findings of others.[14,15] However, the most rigorously designed randomized controlled trial published to date found no significant change in WOMAC scores (pain, stiffness, or function) with hydrotherapy compared with a gym-based strengthening program or no intervention in 105 participants with clinical hip or knee OA.[11] Nevertheless, hydrotherapy did result in improved walking distance and left quadriceps femoris muscle strength compared with no intervention.

In contrast to the program of Foley et al,[11] our aquatic physical therapy program primarily focused on exercises in functional positions, was progressed by increasing resistance (weight bearing or turbulence), and incorporated a walking component, features that may explain our findings of significant improvements in pain and most self-reported and observed physical function measures. Differences in study participants also may account for the conflicting findings. Participants in our study were younger, were more frequently female, and predominantly had knee OA. Importantly, our volunteers were recruited primarily from the community rather than from an orthopedic surgery waiting list (44% of participants in the study of Foley et al[11]), suggesting that aquatic physical therapy may be more effective for less severe OA rather than end-stage disease.

Several reasons may account for the improvements in pain observed in the aquatic physical therapy group. Quadriceps femoris muscle strength is associated with knee pain severity in knee OA,[25,27] although whether muscle weakness causes knee pain or vice versa is unclear at present. Recent work demonstrated an association between hip abductor strength and the knee adduction moment. It has been postulated that stronger hip abductors help to stabilize the contralateral pelvis during walking and, by virtue of the effect on the body's center of mass, can reduce the adduction moment (or compressive force) at the knee.[28] Thus, it is possible that improvements in hip and knee muscle strength were partially responsible for the improvements in knee pain observed in the present study.

Although changes were not statistically significant, aquatic physical therapy did demonstrate a small effect size (.23) for right quadriceps femoris muscle strength and a small but statistically significant effect for the right hip abductors. Conversely, it is also possible that reductions in knee pain were responsible for the small strength gains evident in the present study with aquatic physical therapy. It is difficult to identify the mechanism underlying the observed improvements in strength, but improved recruitment of motor units, muscle hypertrophy, pain alleviation, or reduced knee joint swelling are all possibilities.

A placebo effect of aquatic physical therapy cannot be ruled out because of the lack of a placebo control in the present study. Placebo effects are common in knee OA; reported improvements with sham intervention range from 16% to 40%.[54–57] However, a meta-analysis of placebo-controlled clinical trials[58] demonstrated that placebos have the greatest effect on continuous subjective outcomes and in the treatment of pain, with no significant effect on objective measures. Given that our study demonstrated beneficial effects of aquatic physical therapy on observed objective measures (hip muscle strength and 6-minute walk), it is unlikely that our findings are attributable to a placebo response alone and likely that they may be attributed, at least partially, to the intervention itself.

Joint stiffness was reduced with aquatic physical therapy, and this result may be at least partially attributable to the warm-water environment of the hydrotherapy pool. Warm water may encourage muscle relaxation, thus reducing guarding around joints and enhancing movement. It is also possible that pain relief was achieved by the temperature and pressure of the water on the skin.[59] Although it is possible that some benefits of aquatic physical therapy may be attributable to warm-water immersion alone, a previous randomized controlled trial in rheumatoid arthritis demonstrated superior effects of hydrotherapy over seated immersion alone.[60] Perhaps the most important aspect of the aquatic environment is the buoyancy of the water, rather than its warmth, which reduces the weight-bearing stresses on the lower limbs and thus promotes more pain-free and effective exercise of the muscles and joints than would otherwise be possible.

To our knowledge, this is the first study of aquatic physical therapy that has encouraged ongoing independent aquatic therapy following cessation of the supervised program and incorporated a follow-up period. As part of the intervention, our participants were instructed in the benefits of ongoing therapy and exercise self-management principles, provided with detailed written instructions on how to perform aquatic physical therapy exercises independently as well as how to modify or progress their program according to symptoms, and given written directions on convenient local pools in which to exercise.

Although ongoing adherence among participants was variable, 60% continued aquatic physical therapy independently at least once per week on average. It was not possible to monitor control participants at 12 weeks in the present study, as most of the control group had commenced aquatic physical therapy by this stage. However, follow-up (without a control group) of the aquatic physical therapy group at this time appeared to demonstrate that benefits at 6 weeks were maintained.

Like that of land-based exercise programs, the success of water-based exercise programs is probably partially dependent on adherence to the prescribed exercises. Given the almost perfect attendance demonstrated by our participants during the intervention period, it was not possible to evaluate the relationship between adherence and outcome. In this trial, it is likely that adherence was enhanced by virtue of the close monitoring associated with participation in a research study, and such extremely high levels of adherence should not be expected in the clinical setting. Thus, strategies to maximize adherence are essential for success in clinical practice.

Setting specific exercise-related goals that are relatively easy to achieve has been shown to increase aquatic exercise adherence in people with arthritis.[41] In addition, as people improve in their ability to exercise in the aquatic environment, adherence to exercise increases. Strategies that may promote self-efficacy include beginning slowly with exercises that are easily accomplished, progressing exercise programs slowly, and providing frequent encouragement.[42] Our program was designed to educate participants about the appropriate progression of aquatic exercises, thus optimizing the ability of people to adjust resistance and advance the program themselves or modify it according to symptoms.

Adverse effects associated with our aquatic physical therapy intervention were minor and transient, and over half of the participants experienced no adverse effects at all. As expected, the most frequent complaint was aggravation of joint symptoms with exercise. Some participants also described back pain after commencing exercises; the back pain may have been related to the prompts that they were given to improve their posture and spinal position while walking and exercising in the pool.

Our program did not involve the use of any specific exercise equipment other than a step, which is a feature of most hydrotherapy pools. This study design was used to facilitate participants' understanding of exercise progression in the aquatic environment in order to improve confidence as well as to maximize adherence to the program independently at a local pool during follow-up. The use of equipment (flippers, boots, and floats) can be beneficial for resistance training in the water, and greater strength gains might have been obtained in our study had equipment been incorporated into the program. The fact that quadriceps femoris muscle strength did not increase significantly with our program may argue for the need for equipment for this muscle group in particular. However, the additional benefits of equipment might be offset by increased financial costs of the intervention or by reduced ongoing adherence to the program by participants.

There are a number of limitations of the present study. The lack of a placebo group necessitated a single-blind design, which may have influenced the study outcomes. The follow-up period was short, and in chronic conditions such as OA, much longer periods are warranted to evaluate lasting treatment effects. Furthermore, the follow-up period lacked a control group because of funding constraints. Relatively few of our study participants presented with hip OA primarily; thus, it was not possible to perform subgroup analyses to determine outcomes for hip OA and knee OA separately. It is possible that knee OA and hip OA responded differently to our aquatic physical therapy program, but the present study did not have sufficient power to detect such differences.

The question remains as to whether aquatic physical therapy is superior to land-based physical therapy for OA. Other authors have failed to demonstrate any additional benefit of hydrotherapy over home exercises[12] or over a gym-based strengthening program[11] for people with OA; those results may have been related to the aquatic physical therapy program content in those published trials. Given the association of quadriceps femoris muscle strength with pain severity and physical function in OA,[25,27] it is essential that aquatic programs incorporate a resistance training intensity comparable to that of land-based programs. To increase resistance for muscle strengthening in the water, it may be necessary to further decrease the depth of immersion with closed-chain exercises, to use floats in buoyancy-resisted positions, or to increase resistance from turbulence by increasing speed or surface area (with the addition of flippers or boots) with open-chain exercises. Further studies of aquatic physical therapy should aim to refine program content by maximizing the use of the hydrostatic and hydrodynamic properties of water and thus the potential benefits of aquatic physical therapy for people with lower-limb OA. Future research also should be directed toward evaluating the characteristics of people who respond to land- and water-based exercises, as it is possible that certain types of exercise regimens

are more suitable for particular subgroups of people.

Conclusion

The present study demonstrated that a 6-week program of aquatic physical therapy results in small improvements in pain, stiffness, hip strength, and quality of life in people with hip OA or knee OA compared with no intervention. Aquatic physical therapy is a useful intervention option for such people; many people may adhere to the intervention independently once the supervised program ceases.

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The local Human Research Ethics Committee approved the study.

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