REVIEW ARTICLE

Does Aquatic Exercise Relieve Pain in Adults With Neurologic or Musculoskeletal Disease? A Systematic Review and Meta-Analysis of Randomized Controlled Trials

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ABSTRACT. Hall J, Swinkels A, Briddon J, McCabe CS. Does aquatic exercise relieve pain in adults with neurologic or musculoskeletal disease? A systematic review and meta-analysis of randomized controlled trials. Arch Phys Med Rehabil 2008;89: 873-83.

Objective: To evaluate the literature on the effectiveness of aquatic exercise in relieving pain in adults with neurologic or musculoskeletal disease.

Data Sources: A systematic literature search of 14 databases was examined for research on aquatic exercise over the period January 1980 to June 2006.

Study Selection: Randomized controlled trials (RCTs) that included adults with neurologic or musculoskeletal disease, pain as an outcome measure, and exercise in water were included.

Data Extraction: Information on the participants, interventions, and outcomes was extracted from the included studies. Quality appraisal was assessed using the Scottish Intercollegiate Guidelines Network criteria for RCTs.

Data Synthesis: Nineteen studies met the inclusion criteria; 8 were of moderate to low risk of bias, and 5 of these had data suitable for meta-analyses. This showed that aquatic exercise has a small posttreatment effect in relieving pain compared with no treatment (P=.04; standardized mean difference [SMD], −.17; 95% confidence interval [CI], −.33 to −.01), but it is not possible to draw a firm conclusion because of the lack of consistency of evidence across studies. Comparable pain-relieving effects were found between aquatic and land-based exercise (P=.56; SMD=.11; 95% CI, −.27 to .50).

Conclusions: There is sound evidence that there are no differences in pain-relieving effects between aquatic and land exercise. Compared with no treatment, aquatic exercise has a small pain-relieving effect; however, the small number of good-quality studies and inconsistency of results means that insufficient evidence limits firm conclusions. Future studies should aim for focused research questions on specific aquatic exercise techniques, using robust methodologic designs and detailed reporting of temperature, depth, and care setting.

Key Words: Hydrotherapy; Meta-analysis; Pain; Rehabilitation; Review [publication type].

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EXERCISE IN WARM WATER, usually termed *hydrotherapy* or *aquatic exercise*, is a popular treatment for many patients with painful neurologic or musculoskeletal conditions. Pain-relieving effects have been attributed to a wide variety of mechanisms. For example, the warmth and buoyancy of water may block nociception by acting on thermal and mechanoreceptors, thus influencing spinal segmental mechanisms.[1,2] Also, the warmth of the water may enhance blood flow, which is thought to help in dissipating algogenic chemicals, and it may facilitate muscle relaxation. Other mechanisms are based around the effects of hydrostatic pressure, which by virtue of its effect on the cardiovascular system may relieve pain by reducing peripheral edema[3] and, centrally, by dampening sympathetic nervous activity.[4,5] Finally, the ease of movement many patients report may activate supraspinal pathways, resulting in a reduction in pain intensity.[6] Given the diversity of analgesic pathways it is reasonable to speculate that all patients, irrespective of pain etiology, might benefit from aquatic exercise. Indeed, aquatic exercise is widely recognized as an important modality in the rehabilitation of patients with rheumatologic, orthopedic, and neurologic disorders.[7]

In the United Kingdom, aquatic exercise for therapeutic purposes is recognized as a physical therapy−led treatment that uses the unique properties of water, "ideally in a purpose built, and suitably heated pool."[8(p5)] This definition differs from the European approach in which balneotherapy, the medical application of natural thermal mineral waters, is usually associated with passive bathing, although sometimes exercise may be included.[1,2] Despite the obvious differences between the 2, systematic reviews of balneotherapy have informed aquatic therapy practice.[9-13] Only 1 systematic review, conducted by a single reviewer, has been performed on aquatic exercise.[14] It considered all study designs, including those with co-interventions, and provides a detailed qualitative account of the effects of hydrotherapy on all outcomes mentioned. It did not specifically explore the effect of aquatic exercise on pain; nor did it evaluate the raw data on pain.

In this study, we report a systematic review and meta-analysis of published randomized controlled trials (RCTs) that addresses the question: Does aquatic exercise relieve pain in adults with neurologic or musculoskeletal disease? This question has 2 elements: (1) Is aquatic exercise an effective treatment for pain (ie, better than no treatment)? and (2) How does

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Potentially relevant RCTs identified and screened for retrieval: N=793

RCTs excluded, with reasons: n=729

1. Non-human	5	6. Too general	33
2. Not adult	10	7. Not RCT	35
3. Water activity unrelated to aquatic exercise	239	8. Irrelevant publication	25
4. Inappropriate pathology	63	9. Aquatic exercise unlikely to be treatment modality	22
5. Aquatic exercise incidental to study	74	10. Duplicates	223

RCTs retrieved for more detailed evaluation: n=64 (+5 from reference searching)

RCTs excluded, with reasons:

1. Not RCT 21
2. Co-interventions (educational) were present 6
3. Not aquatic exercise (as defined) 17
4. Inappropriate pathology 2
5. Pain not an outcome measure 4

RCTs suitable for full paper review n=19

Potential RCTs for meta-analyses
- Aquatic exercise vs no treatment n=9
- Aquatic exercise vs land exercise n=10
- Aquatic exercise vs immersion n=2

RCTs excluded from meta-analyses, with reasons:
- Aquatic exercise vs no treatment: 4 high risk of bias; 2 inappropriate raw data
- Aquatic exercise vs land exercise 6 high risk of bias: 2 inappropriate raw data
- Aquatic exercise vs immersion 1 inappropriate data

Actual RCTs included in meta-analyses
- Aquatic exercise vs no treatment n=3
- Aquatic exercise vs land exercise n=2
- Aquatic exercise vs immersion n=0

Fig 1. Trial flow.

pain relief in aquatic exercise compare with other interventions?

METHODS

Search Strategy

A search strategy was developed by iterative exploration of 18 databases using a variety of search terms that emphasized sensitivity (high recall) over specificity (precision).[15] In the final search strategy, studies were sought from 14 databases, including Medline, AMED, EMBASE, SportDiscus, PEDro, CINAHL, ASSIA, and the Cochrane Library. Over the period January 1980 to June 2006, we used a range of search terms based around the concepts of aquatic exercise (*hydrother$*, *balneo$*, *aquarobic$*, *aquatic rehab$*, *aqua$ and exercise*, *water and gymnast$*, *water aerobic$*) and pain using the International Association for the Study of Pain terminology.[16] Reference and bibliographic lists of retrieved articles and relevant reviews were also examined. The search was limited to English-language works and those that studied adults (people aged ≥18y).

Study Selection

A 3-stage process was used to select studies for inclusion in the review. In the first stage, the title of each identified article was checked against predetermined criteria by 2 reviewers using a standard form and coding sheet. Abstracts and full articles were similarly reviewed in the next 2 stages. In general, a policy of inclusion was adopted—that is, in the absence of any information to the contrary, each article was forwarded to the next stage of the screening process. Criteria for inclusion were titles, abstracts, and/or articles that suggested some aspect of aquatic exercise as defined in adults with neurologic or musculoskeletal pathology and with pain as an outcome measure. In addition, included studies were limited to full reports of RCTs that examined the effectiveness of aquatic exercise compared with no treatment or other interventions, such as land-based exercise or immersion, in adult patients (≥18y) with any neurologic or musculoskeletal pathology and in which at least 1 outcome measure of "subjective pain experience captured by ratings of pain intensity, sensation, and unpleasantness" was reported.[17] Studies that considered the prevention of pain in healthy conditions (eg, pregnancy) or which incorporated additional interventions (eg, education) were excluded from the review.

Validity Assessment

Selected studies were subject to unmasked quality assessment[18] by 2 reviewers using the criteria for RCTs recommended by the Scottish Intercollegiate Guidelines Network (SIGN 50).[19] An overall assessment of the 9 questions provides a bias rating of low (++), moderate (+), or high (−). A low bias rating indicates a high-quality study in which all or most of the 9 criteria have been fulfilled and where they have not been fulfilled the conclusions of the study are thought unlikely to alter. One study was authored by a reviewer and was therefore assessed by another independent reviewer.

Data Extraction and Analysis

Data extraction was completed using a pilot-tested form to capture information on a range of details including study design, participants, interventions, and outcome measures. All of the primary pain outcomes were continuous and, where it was possible to pool data, meta-analysis was conducted on the results of studies of high to moderate quality[20] using the Cochrane Collaboration's review manager software.[a] Tables of comparisons were set up comparing aquatic exercise with no treatment and with interventions of dry-land exercise and immersion. A random effects model, weighted by sample size, was used to analyze end scores based on posttreatment differences between aquatic exercise and these comparison groups.[21] Changes in these scores (effect sizes = [mean1 − mean2]/pooled standard deviation [SD]) and 95% confidence intervals (CIs) were measured in units of SD (standardized mean difference [SMD]) and illustrated graphically using forest plots.

Variation in the measured effect was explored using a statistical test for heterogeneity; nonsignificance indicates that the results of the different studies are similar.[22] When possible, sensitivity was examined by assessing the effect of removing studies with small sample sizes (low weighting) from the analysis. In addition, between-group differences for all studies, irrespective of quality, were examined for consistency and, in the absence of suitable data, study texts and significance tests were scrutinized. Conclusions were based on both quantitative and qualitative assessment of studies with low to moderate risk of bias.

RESULTS

Trial Flow

Seven hundred ninety-three publications were identified and screened against the inclusion and exclusion criteria. Of these publications, 729 were rejected at the title and abstract stage (fig 1). Sixty-nine studies proceeded to the paper screening stage, and 19 of these were accepted for review.[23-41] Of the 19, 5 studies were of sufficient quality and had adequate raw data to be entered into meta-analyses under one of 2 comparisons: aquatic exercise versus no-treatment controls and aquatic versus dry land exercise. The study selection and validity assessment process was undertaken by 2 independent reviewers. Where anomalies existed, discussion between the reviewers enabled consensus to be achieved.

Study Characteristics

Nine studies compared aquatic exercise with no-treatment or waiting-list control groups,[26,28,30,32,33,35,38,39,41] 10 compared it with land exercise,[23-25,27,29,31,34,35,37,40] and 2 with immersion[27,36] (table 1). Two studies incorporated more than 2 treatment arms.[27,35]

Participants

Within the 19 studies, 717 patients participated in hydrotherapy, with an average age of 56.0±11.3 years (range, 25–81y) and, based on available data, an overall men-to-women ratio of 1:3 (not all studies reported this). The number of subjects randomized to the aquatic exercise arm ranged from 7 to 153, with 1 study omitting to report how many patients were randomized to the different treatment arms.[34] Most patients presented with rheumatology conditions, and only Sutherland et al[33] involved patients with neurologic problems. Of the rheumatology articles, 4 considered fibromyalgia,[31,36,40,41] 3 chronic low back pain,[29,30,37] and 11 osteoarthritis or rheumatoid arthritis.[23-28,32,35,38,39] The duration of symptoms varied from 2.75 to 24.00 years with an average of 9.98±5.50 years.

Drop-out rates for aquatic exercise patients ranged from 0% to 27.4%. Of the 3 studies with drop-out rates exceeding 20% (SIGN criterion), the time from baseline to posttest varied from 6 to 52 weeks. Extraneous causes such as comorbidity, time issues, or travel difficulties were responsible rather than the deleterious side effects of treatment. Three authors reported that a few patients (n=5) experienced an exacerbation of symptoms, but from the information provided, the treatment group affiliation of these patients is difficult to determine.[25,29,35]

Intervention

Thirteen articles reported the aims of the aquatic exercise intervention and details, however brief, of the specific activities were mentioned in all. By categorizing the activities, it was possible to identify 3 types of exercise program: a general exercise program that included elements of muscle strengthening, increasing range of movement, and functional activities (n=9)[24-27,29,30,32,34,36]; aerobic exercise (n=9)[23,28,31,33,37-41]; and strengthening exercise (n=1).[35] Of the 9 articles in which aerobic exercise was reported, 5 based the exercise intensity on heart rate.[23,28,31,40,41]

The intervention setting in 12 studies indicated that hospital or clinic pools were used. Three used community or public swimming pools, and 4 omitted to report the treatment setting. The overall duration of aquatic exercise treatment ranged from 6 weeks or less[27,30] to more than 12 weeks,[28,31,32,39,40] with an average of 33.25±19.20 sessions. Treatments took place on an outpatient basis 2 to 3 times a week for a minimum of 30 and a maximum of 75 minutes (mean, 50.7±12.2min); 3 studies did not report session duration.[25,34,37] Total treatment time ranged from 4 to 84 hours (mean, 25.5±20.54; median, 22.5). Where reported, treatment was performed in groups of 4 to 24 patients supervised by physiotherapists (n=8) or trained instructors (n=5) and using programs designed by a physiotherapist or fitness professional (n=5). In 11 studies, the average temperature of the water was 32.4°±2.7°C (range, 28°–36°C). Only 4 studies reported the depth of the water,[23,25,34,41] which was between waist and chest height.

Outcome Measurement

Pain outcomes were measured before and after intervention in each reviewed study; follow-up data were reported in 8 studies.[23,25,27,31,36,38,39,41] A variety of instruments were used to measure sensory pain, with the 10-cm visual analog scale (VAS) being the most common.[24-26,28,29,31,34,36,37,40,41] Other instruments included the McGill Pain Questionnaire[27,30] and pain subscales from a variety of self-report questionnaires (Arthritis Impact Measurement Scale,[23] Health Assessment Questionnaire,[32] health-related quality of life,[33] Western Ontario and McMaster Universities Osteoarthritis Index [WOMAC],[35,39] 36-Item Short-Form Health Survey[38]). Only 3 studies included pain as a primary outcome measure,[39-41] and 2 of these had used this pain outcome in a power calculation for sample size.

Methodologic Quality

Five studies were judged to be at low risk of bias using the SIGN criteria and are therefore judged as high quality.[27,32,35,39,40] Three studies were of moderate[26,31,38] and 11 studies[23-25,28-30,33,34,36,37,41] of low quality (table 2). Although all studies were described as randomized, most (91%) of those that had a high level of bias failed to meet this SIGN criterion. Other criteria that were frequently inadequate included randomization concealment and intention-to-treat analysis (both n=14 [73.6%]). Although a priori power calculations are not included within the SIGN checklist we noted that only 6 studies[27,30,32,35,39,40] included any sample size power calculations and that 3 of these[35,39,40] were based on pain outcomes. Five studies[23,27,30,32,39] were independently powered to detect either a clinically meaningful or a conventionally large effect size for pain.[42-44]

Aquatic Exercise Versus No-Treatment Controls

Of the 9 studies in this comparison,[26,28,30,32,33,35,38,39,41] 5 were of moderate to high quality,[26,32,35,38,39] and of those, 3 had data suitable for incorporation into a meta-analysis[32,38,39] (fig 2A). This showed a small posttreatment effect in favor of aquatic exercise (P=.04; SMD=−.17; 95% CI, −.33 to −.01) (see fig 2A). Removing the smallest study[38] (n=22) from the

Table 1: Summary Description of the 19 Studies Included in the Review

Study (Country)	Participants A. Condition B. Duration of symptoms (mean ± SD; range [y]) C. Age (mean ± SD; range [y]) D. Men:women	Comparison Groups	Intervention A. Aims and content B. Duration of program C. Setting and pool temperature	"Primary" Pain Outcomes and Timing	Results of "Primary Pain Outcomes" According to Study	Calculated Effect Size (95% CI)
Minor et al[23] (USA)	A. RA and OA B. RA: 10.8±7.9; OA: 14.6±10.7 C. 60.63 (21−83) D. 22:98	1. Aquatic exercise (n=47) 2. Land-based exercise: aerobic walking (n=36) 3. Land-based exercise: range of motion (n=32)	A. The aim of groups 1 and 2 was aerobic conditioning. Participants exercised at 60%−80% of maximal heart rate. B. 60min 3 times a week for 12wk C. NR	Pain subscale of AIMS at 0, 12, 24, and 52wk	Significant improvement of all groups at different time points (*P*<.05). No significant differences between interventions.	0.28 (–0.21 to 0.76)
Sylvester[24] (UK)	A. Hip OA B. 4 (2−8) C. 66 (9−81) D. 5:9	1. Aquatic exercise (n=7) 2. Land-based exercises and short-wave diathermy (n=7)	A. Both groups performed hip exercises and walking B. 30min twice a week for 6wk C. NR	VAS at 0 and 7wk	Significant improvement in both groups (*P*<.02). No significant differences between interventions.	DNA
Green et al[25] (UK)	A. Hip OA B. NR C. 68±NR D. 12:35	1. Aquatic exercise (n=24) 2. Land-based exercise (n=23)	A. Both groups: to mobilize and strengthen hip B. Twice weekly for 6wk C. Hospital pool (temp NR ([deep pool])	VAS at 0, 3, 6, 9, 12, and 18wk	Significant improvement in both groups. No significant differences between interventions.	DNA
Ahern et al[26] (Australia)	A. RA/OA B. 9.4±12 C. 67.7±7.1 D. 17:13	1 Aquatic exercise (n=22) 2. No-treatment control (n=8)	A. Group 1: to maximize mobility and function, reduce pain in the target joints B. 30min twice a week for 6wk C. Hospital pool, 34°C	VAS for pain at 1, 2, 4, 6wk	At study end patients who continued with aquatic exercise after phase 1 maintained improvement in pain relief, whereas those who were assigned to the no-treatment control group did not.	DNA
Hall et al[27] (UK)	A. RA B. 11.5±8.7 C. 58.2±11.1 D. 43:96	1. Aquatic exercise (n=35) 2. Land-based exercise (n=34) 3. Immersion (n=35) 4. Land relaxation (n=35)	A. Groups 1 and 2: to increase ROM and muscle strength of upper and lower limbs B. 30min twice a week for 4wk C. Hospital pool (temp NR)	McGill Pain Questionnaire at 0, 4, and 12wk	No significant differences between interventions.	0.10 (–0.37 to 0.57)
Rintala et al[28] (Finland)	A. RA B. 1.4 (1−27) C. 48±10 D. 5:29	1. Aquatic exercise (n=18) 2. No-treatment control (n=16)	A. Group 1: to improve fitness, including aerobic power, muscle strength and endurance, and joint mobility. Ratings of perceived exertion used as measure of exercise intensity. B. 45−60min twice a week for 12wk C. NR	VAS at 0 and 12wk	Aquatic exercise relieved pain significantly compared with control (*P*=.044).	–0.87 (–1.58 to –0.17)

Table 1 (Cont'd): Summary Description of the 19 Studies Included in the Review

Sjogren et al[29] (Australia)	A. CLBP B. 8.72±7.13 C. 57.7±12.6 D. 17:43	1. Aquatic exercise (n=30) 2. Land-based exercise (n=30)	A. Aim of both groups was to increase truncal movement, improve general strength and endurance B. 50min twice a week for 6wk C. NR	VAS at baseline and 6wk	Significant improvement of both groups (*P*=.001). No significant differences between interventions.	–0.02 (–0.54 to 0.51)
McIlveen and Robertson[30] (Australia)	A. CLBP B. 10.13±NR C. 57.8±15.1 D. 38:57	1. Aquatic exercise (n=56) 2. Waiting list control/no treatment (n=53)	A. Group 1: general exercises for the spine B. 60min twice a week for 4wk C. NR	McGill Pain Questionnaire at 0 and 4wk	No significant differences between interventions.	DNA
Jentoft et al[31] (Norway)	A. Fibromyalgia B. 11.1±14.1 C. 42.9±8.6 D. 0:44	1. Aquatic exercise (n=22) 2. Land-based exercise (n=22)	A. Both groups: to improve cardiovascular capacity using the Norwegian aerobic fitness model. Participants exercised at 60%–80% of predicted maximal heart rate for 40%–50% of each session. B. 60min twice a week for 20wk C. Hospital pool, 34°C	VAS at 0, 24, and 46wk	Significant improvement in aquatic exercise group (*P*=.006). No significant differences between interventions.	0.14 (–0.45 to 0.74)
Patrick et al[32] (USA)	A. OA B. NR C. 65.7±NR D. 34:214	1. Aquatic exercise (n=124) 2. No treatment/delayed treatment (n=125)	A. Group 1: consisted of Arthritis Foundation–certified aquatic class B. 45–60min at least twice weekly for 20wk C. Community pools, 29.5°–33.3°C	Pain subscale of HAQ at 0 and 20wk	No significant differences between interventions.	–0.12 (–0.37 to 0.13)
Sutherland et al[33] (Australia)	A. Multiple sclerosis B. 10.8±NR C. 46.3±4.9 D. 10:12	1. Aquatic exercise (n=11) 2. No-treatment control (n=11)	A. Group 1: water aerobics, water jogging, deep water running B. 45min 3 times a week for 10wk C. NR	Pain subscale of MSQOL-54 at 0 and 8wk	Aquatic exercise relieved pain significantly compared with control (*P*=.01).	0.21 (–0.60 to 1.04)
Wyatt et al[34] (Sweden)	A. Knee OA B. NR C. NR (45–70) D. NR	1. Aquatic exercise 2. Land-based exercise (overall, n=46)	A. Both groups performed knee exercises B. 3 times a week for 6wk C. Therapeutic pool, 32.2°C (1.5m [5ft] deep)	VAS at 0 and 6wk	Aquatic exercise relieved pain significantly compared with control (*P*≤.05).	–0.86 (–1.49 to –0.22)
Foley et al[35] (Australia)	A. Hip/knee OA B. NR C. 70.9±8.8 D. 53:52	1. Aquatic exercise (n=35) 2. Land-based exercise (n=35) 3. No-treatment control (n=35)	A. Groups 1 and 2: to strengthen lower-limb musculature and improve physical function. B. 30min 3 times a week for 6wk C. Hospital pool, gym (temp NR)	Pain subscale of WOMAC at 0 and 6wk	Significant improvement in aquatic exercise group (*P*=.045). No significant differences between interventions.	DNA
Altan et al[36] (Turkey)	A. Fibromyalgia B. NR C. 43.14±6.4 D. 0:50	1. Aquatic exercise (n=25) 2. Immersion (n=25)	A. Group 1: walking, jumping, active ROM exercise for the neck and extremities, stretching, relaxation. Group 2: patients were instructed not to perform any exercises. B. 70min 3 times a week for 12wk C. Therapeutic pool, 37°C	VAS at 0, 12, and 24wk	Significant improvement of both groups (*P*<.05). No significant differences between interventions.	0.08 (–0.48 to 0.63)

Table 1 (Cont'd): Summary Description of the 19 Studies Included in the Review

Yozbatiran et al[37] (Turkey)	A. CLBP B. NR C. 39.07±6.35 D. 7:23	1. Aquatic exercise (n=15) 2. Land-based exercise (n=15)	A. Both followed the program advocated by Frost et al[63] including warm-up, stretching, circuit of 15 progressive exercises, cool down with light stretching and light aerobic exercise. B. 3 times a week for 12wk C. NR	VAS for pain at 0 and 4wk	Significant improvement of both groups (*P*=.02). No significant differences between interventions.	–0.36 (–1.08 to 0.36)
Bilberg et al[38] (Sweden)	A. RA B. 2.75±1.37 C. NR (21–65) D. 5:42	1. Aquatic exercise (n=22) 2. No-treatment control/ usual home exercises (n=25)	A. Group 1: exercises for aerobic capacity, dynamic and static muscle strength in upper and lower limbs, flexibility, coordination, and relaxation B. 45min twice a week for 12wk C. NR, temperate pool	Pain subscale of SF-36 at 1 and 12wk (and for aquatic exercise group 24wk)	Significant improvement of both groups (*P*<.05). No significant differences between interventions.	0.00 (–0.60 to 0.59)
Cochrane et al[39] (UK)	A. Lower-limb OA B. NR C. 69.7±6.5 D. 116:196	1. Aquatic exercise (n=153) 2. No-treatment control (n=159)	A. Group 1: standard 5-phase exercise protocol consisting of warm-up, joint ROM exercises, muscle strengthening, coordination and balance exercises, and general cardiovascular conditioning exercises B. 60min twice a week for 1y C. Public swimming pools, 28°–33°C.	Pain subscale of WOMAC at 0, 12, and 18mo	Aquatic exercise relieved pain significantly compared with control (*P*=.031). Improvements had been lost by follow-up.	–0.24 (–0.47 to –0.02)
Assis et al[40] (Brazil)	A. Fibromyalgia B. 6.04±4.86 C. 42.8±10.4 D. 0:60	1. Aquatic exercise (n=30) 2. Land-based exercise (n=30)	A. Both groups: aerobic conditioning using heart rate at anaerobic threshold as intensity marker. B. 45min 3 times a week for 15wk C. Sport and physical medical center and local park, 28°–31°C	VAS for pain at 0, 8, and 15wk	Significant improvement of both groups (*P*<.001, pain reduced by 36%). No significant differences between interventions.	DNA
Gusi et al[41] (Finland)	A. Fibromyalgia B. 21.5±8.5 C. 51±9.5 D. 0:35	1. Aquatic exercise (n=18) 2. No-treatment control (n=17)	A. Group 1: exercise included warm-up, aerobic exercise at 65%–75% predicted maximal heart rate, overall mobility and lower-limb strength exercises and cool down B. 60min 3 times a week for 12wk C. NR, 33°C (waist-high pool)	VAS for pain at 0, 12, and 24wk	Aquatic exercise relieved pain significantly compared with control (*P*<.05). Improvements had been lost by follow-up.	DNA

Abbreviations: AIMS, Arthritis Impact Measurement Scale; CLBP, chronic low-back pain; DNA, data not available for effect size calculation; HAQ, Health Assessment Questionnaire; MSQOL-54, Multiple Sclerosis Quality of Life–54; NR, not recorded; OA, osteoarthritis; RA, rheumatoid arthritis; ROM, range of motion; SF-36, 36-Item Short Form Health Survey; VAS, visual analog scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

Table 2: Quality Assessment of the 19 Studies Included in the Review Using Modified SIGN Criteria for RCTs

Study	Clear Question	Acceptable Randomization Method	Adequate Concealment Method	Blinding of Assessors	Groups Similar at Baseline	Only Difference Between Groups Is Aquatic Exercise Intervention	Outcomes Measurement: Standard, Valid, and Reliable?	Percentage of Drop-Outs Before Posttest	ITT	Overall Bias Rating
Ahern et al[26]	WC	WC	NA	AA	PA	NR	AA	NA	NA	+
Altan et al[36]	WC	PA	NA	WC	WC	PA	WC	Gp1=4 Gp2=12	NA	–
Assis et al[40]	WC	WC	WC	WC	WC	NA	WC	Gp1=13.3 Gp2=14.8	WC	++
Bilberg et al[38]	AA	AA	AA	AA	WC	NR	AA	Gp1=0 Gp2=0	NA	+
Cochrane et al[39]	WC	WC	WC	WC	WC	WC	WC	Gp1=27.4 Gp2=24.5	WC	++
Foley et al[35]	WC	WC	WC	AA	WC	AA	WC	Gp1=20 Gp2=25.7 Gp3=8.6	WC	++
Green et al[25]	AA	PA	NA	PA	PA	PA	PA	Overall=25	NA	–
Gusi et al[41]	AA	NR	NA	NA	AA	NA	AA	Gp1=5.5 Gp2=0	NR	–
Hall et al[27]	WC	WC	AA	AA	WC	AA	WC	Overall=6	NA	++
Jentoft et al[31]	WC	AA	NA	WC	WC	WC	WC	Gp1=18 Gp2=27	NA	+
McIlveen and Robertson[30]	AA	PA	NA	AA	PA	AA	WC	Gp1=19.6 Gp2=5.6	NA	–
Minor et al[23]	AA	NR	NA	NA	WC	WC	AA	Gp1=14.9 Gp2=22 Gp3=12.5	NA	–
Patrick et al[32]	WC	WC	NA	NApp*	WC	WC	WC	Gp1=16.8 Gp2=3.0	WC	++
Rintala et al[28]	WC	AA	NA	NA	AA	AA	AA	Gp1=5.5 Gp2=18.7	NA	–
Sjogren et al[29]	AA	PA	NA	AA	AA	AA	AA	Gp1=6.7 Gp2=6.7	NA	–
Sutherland et al[33]	AA	NR	NA	PA	AA	AA	AA	NA	WC	–
Sylvester[24]	AA	NR	NA	AA	AA	AA	AA	Gp1=0 Gp2=0	NA	–
Wyatt et al[34]	AA	NR	NA	AA	NA	AA	PA	Overall=8.7	NA	–
Yozbatiran et al[37]	WC	NA	NA	NA	AA	PA	AA	NA	NA	–

Abbreviations: AA, adequately addressed; Gp, group; ITT, intention-to-treat analysis (all subjects are analyzed in the groups to which they were randomly allocated); NA, not addressed; NApp, not applicable; NR, not reported; PA, poorly addressed; WC, well covered.
Legends: +, some of the criteria have been fulfilled. Where they have not been fulfilled the conclusions of the study are thought *unlikely* to alter; ++, all or most of the criteria have been fulfilled. Where they have not been fulfilled the conclusions of the study are thought *very unlikely* to alter; –, few or no criteria fulfilled. The conclusions of the study are thought *likely* or *very likely* to alter.
*The outcomes consisted of self-administered postal questionnaires only.

analysis altered the SMD slightly from −.17 to −.19 (95% CI, −.35 to −.02) and the level of significance to *P* equal to .03. Statistical tests for heterogeneity were not significant. Qualitative analysis, based on review of results reported by researchers showed a lack of consistency between study results, whether of high or low quality. In summary, the evidence shows a small beneficial treatment effect in favor of aquatic exercise compared with no treatment. Only 1 study in the meta-analysis[39] independently showed an effect size in favor of pain relief (for WOMAC pain) that is clinically meaningful.[42] However, the small number of good-quality studies that could be included into the meta-analysis and the inconsistency of results across all the studies suggest that, currently, we have insufficient evidence to categorically state that aquatic exercise is an effective modality for relieving pain.

Aquatic Exercise Versus Land Exercise

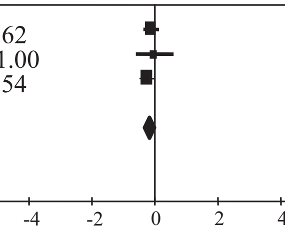
Ten studies were identified in this comparison[23-25,27,29,31,34,35,37,40]; one of these was assessed as moderate quality[31] and 3 as high quality.[27,35,40] Meta-analysis of the moderate- to high-quality studies with available data[27,31] showed no differences between aquatic exercise and land-based exercise (*P*=.56; SMD=.11; 95% CI, −.27 to .50) (see fig 2B). Data in the remaining 2 high-quality studies, reported as median and interquartile ranges for the WOMAC[35] and pain VAS,[40] are consistent with these findings. Of the poor-quality studies, only one[34] contradicts the overall consistency of results. In summary, the evidence—based on meta-analysis and overall consistency of results—suggests that aquatic exercise and land-based exercise have comparable pain-relieving effects.

A

Comparison: Aquatic exercise versus no-treatment control group
Outcome: Pain at end of intervention period

Study	N	Aquatic Exercise (mean ± SD)	N	No-Treatment Control (mean ± SD)	SMD (random) 95% CI	Weight %	SMD (random) 95% CI
Patrick et al[32]	124	1.38±0.74	125	1.46±0.62		42.05	−0.12 (−0.37 to 0.13)
Bilberg et al[38]	20	50.80±23.40	23	50.90±21.00		7.24	0.00 (−0.60 to 0.59)
Cochrane et al[39]	151	8.46±3.74	151	9.35±3.54		50.71	−0.24 (−0.47 to −0.02)
Total (95% CI)	295		299			100.00	−0.17 (−0.33 to −0.01)

Test for heterogeneity: χ^2=.88, *df*=2 (*P*=.65), I^2=0%
Test for overall effect: *z*=2.10 (*P*=.04)



B

Comparison: Aquatic exercise vs land based exercise
Outcome: Pain at end of intervention period

Study	N	Aquatic Exercise (mean ± SD)	N	Land-Based Exercise (mean ± SD)	SMD (random) 95% CI	Weight %	SMD (random) 95% CI
Hall et al[27]	35	2.64±0.70	34	2.57±0.70		67.10	0.10 (−0.37 to 0.57)
Jentoft et al[31]	18	5.60±2.30	16	5.20±3.10		32.90	0.14 (−0.53 to 0.82)
Total (95% CI)	53		50			100.00	0.11 (−0.27 to 0.50)

Test for heterogeneity: χ^2=.01, *df*=1 (*P*=.91), I^2=0%
Test for overall effect: *z*=.58 (*P*=.56)

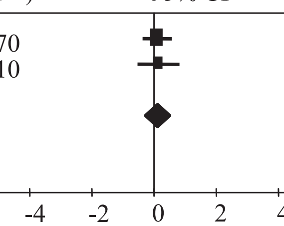


Fig 2. Meta-analysis of trials with moderate to low risk of bias. (A) Aquatic exercise versus no-treatment control group. (B) Aquatic exercise versus land-based exercise. The forest plots show the differences between aquatic exercise and no-treatment control groups and land exercise. Included are the means ± SD for each group, sample size, SMD, 95% CIs and the weighting for each study, and the combined results.

Aquatic Exercise Versus Immersion

Two studies were identified in this comparison.[27,36] One of these was assessed as low quality[36]; meta-analysis of the data of these studies was therefore not performed. Neither study found any postintervention differences in pain outcomes between aquatic exercise and immersion groups. At present, the small number of good-quality studies hampers firm conclusions about the benefits of exercise in water versus immersion.

DISCUSSION

Is Aquatic Exercise an Effective Treatment for Pain?

When compared with no-treatment controls, meta-analysis shows a small but significant posttreatment effect in favor of hydrotherapy. The 95% CI for this effect comes close to, but does not cross, the line of no treatment effect. In 2 of the studies in the meta-analysis, exercise was performed in water ranging from 29.5° to 33.5°C[32,39]; temperature was described as "temperate" in one.[38(p503)] This encompasses a wide range of water temperature from cool to near thermoneutral (usually described as 34.5°–35°C). There is an assumption, by therapists and patients alike, that warmer water is more conducive to pain relief, and the mechanisms whereby heat alters pain perception are well known. Neuromuscular, hemodynamic, and metabolic responses to skin heating have been described[45,46]; however, skin heating through whole-body immersion and core body temperature changes during exercise in water await investigation. The contribution of the warmth of the water to pain relief during hydrotherapy therefore remains speculative.

Several researchers have also reported a relationship between water temperature and adherence, which suggests that thermal comfort is an important environmental factor in patients with a similar profile to those in the studies included in this review.[39,47] Our review found evidence that aquatic exercise has a small effect in relieving pain even at cooler temperatures below thermoneutral. Potentially, this has important implications in terms of water heating costs. In addition, it suggests that effective aquatic exercise can be practiced in community settings that traditionally maintain lower temperatures than hospital-based pools.

Forty-two percent of studies in this review failed to cite water temperature and, because it is considered a critical variable, this should be reported in future aquatic exercise studies. Also, some studies fail to explicitly state the aim of the water-based exercise program and/or to provide an adequate description of its type and intensity (n=6 [31.5%]). The effect of exercise-induced analgesia on pain suggests that pain intensity is reduced after exercise.[48] However, in humans, consistent results have been shown only for high-intensity land exercise (ie, ≥70% of maximal aerobic capacity). Exercise prescription is commonly based on predicted maximal heart rate because of the linear relationship between aerobic capacity and heart rate.[49] However, Tanaka et al[50] have recently questioned the accuracy of exercise prescription based on predicted maximal heart rate, particularly in older people. Furthermore, the variable effect of water temperature on heart rate makes it uncertain that the exercise intensity in the studies reviewed was above the analgesic threshold.[51]

The interaction between exercise intensity and water temperature, as well as having practical considerations,[52] may affect pain differentially. In addition, water depth alters the nature of exercise through buoyancy and hydrostatic pressure. This in turn may influence the physiologic mechanisms underlying pain relief through the relationship between cardiovascular and pain regulatory pathways.[53]

The duration of the aquatic exercise program is another variable that may play a significant role in pain relief. In his review Janal[54] highlights the uncertainty for the optimal duration of exercise-induced analgesia but suggests that the interaction between intensity and duration affects exercise-induced hypoalgesia. We noted that duration of treatment varied from twice a week for 4 weeks[27] to 4 times a week for 53 weeks.[39] The 3 studies[32,38,39] comparing aquatic exercise and no-treatment controls are homogenous in terms of the type of exercise performed within the pool environment, but they have different durations of intervention, ranging from 12 to 52 weeks on a twice-weekly basis. It is interesting that those studies that do not report significant differences between groups are those of shorter duration. The duration of aquatic exercise programs for maximum pain relief is both clinically and economically important and warrants further investigation by good-quality longitudinal follow-up studies.

How Does Aquatic Exercise Compare With Other Interventions?

There is a general assumption that hydrotherapy will provide better pain relief than either land-based exercise or immersion alone. However, we found no significant differences between hydrotherapy and immersion in the 2 studies available.[27,36] In addition, no significant between-group differences were noted between aquatic and land-based exercise, which suggests that for those who find exercise on land challenging or tedious, exercise in water provides a similar effect. This lack of difference has been reported in previous studies,[23,31,40] and currently, given the paucity of evidence, it is difficult to speculate which of the many variables (ie, temperature, exercise intensity and duration, treatment setting) could, either independently or in combination, be critical in pain relief. In contrast to our findings, the popularity of aquatic exercise as a modality for pain relief suggests that any additional benefits compared with land exercise have not yet been captured by the research.

Features of This Review

The impetus for this review was our perception of a disparity between anecdotal reports of significant pain relief from aquatic exercisers and our informal reading of the literature. Thus we chose to focus on the outcome, pain, rather than a specific population. In focusing on pain, we made an a priori selection of the primary pain outcome measure based on the availability of raw data and the most frequently occurring measure across all studies when multiple outcomes for this variable were cited. The lack of consistency in pain outcome measurements across the studies validated our decision to limit our definition to pain intensity; future reviews might be able to incorporate evaluations of pain behavior and cognitive coping strategies as prospective studies include such measures. We selected the RCT checklist produced by SIGN, one of many quality assessment tools, which allows overall assessment of individual components and is included in best practice systems reported by the Agency for Healthcare Research and Quality. However, as Katrak et al[55] point out, there is no criterion standard for quality assessment tools in allied health research, and so our results must be considered in the light of the instrument we used.

Key Recommendations for Future Research in Hydrotherapy

We noted a number of substantial research design issues with 57.8% of the studies having important methodologic flaws. Most of these flaws related to aspects of RCT design such as randomization, allocation concealment, and blinding to outcome measurement. In addition, inadequate reporting of the intervention—in terms of setting, water temperature, depth, aim, type, and intensity of exercise—meant that some studies may have been downgraded as a result of poor reporting. Jüni et al[56] defend this "guilty until proven innocent" argument with the justification that faulty reporting generally reflects poor methodology. Lack of resources meant that we were unable to contact researchers for further information. We acknowledge the impossibility of patient blinding to aquatic exercise; however, other approaches such as blinding of patients to the research hypothesis and evaluation of the expectations of patients and practitioners are possible and may be particularly important for pain and other self-reported outcome.[57,58] Many of the studies included in this review were general studies of aquatic exercise effectiveness that lacked a primary outcome measure, appropriate power, and adequate follow-up periods. Future studies should address these deficits by including specific details of the intervention, careful and creative consideration of both RCT design and of the literature on minimum clinically important differences for the primary outcome of interest (eg, for pain[42,43,59]), and comprehensive reporting based on current recommendations.[60] We noted, as did Geytenbeek,[14] that aquatic exercise research concentrates almost exclusively on chronic musculoskeletal conditions. However, the increasing use of aquatic exercise for patients with neurologic disorders suggests that this area is ripe for research.[61,62] Finally, given the importance of predicting patient outcome, data analysis on the basis of improvement versus deterioration and adherence versus nonadherence is also recommended.

CONCLUSIONS

In contrast to anecdotal reports of superior pain relief from aquatic exercise, our review shows that water and land-based exercise are similar, although when compared with no treatment, exercise in water provides limited analgesia. Inconsistent results in studies with no-treatment comparison groups combined with the design flaws and reporting omissions throughout the studies reviewed suggests that large, pragmatic studies are required to establish the optimal combinations of exercise type, duration, water temperature and depth, and service delivery for diverse patient populations. Furthermore, discrepancy between the perceived value of hydrotherapy in clinical practice and our findings justifies future research endeavors.

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