Effectiveness of Aquatic Exercise in Improving Lower Limb Strength in Musculoskeletal Conditions: A Systematic Review and Meta-Analysis

Sophie Heywood, MPhysio (Sports), a,b Jodie McClelland, PhD, c Benjamin Mentiplay, BEcSci,a Paula Geigle, PhD, d Ann Rahmann, PhD, e Ross Clark, PhD f

From the aFaculty of Health Sciences, School of Exercise Science, Australian Catholic University, Melbourne, VIC, Australia; bThe Melbourne Sports Medicine Centre, Melbourne, VIC, Australia; cLatrobe University, Melbourne, VIC, Australia; dSchool of Medicine, University of Maryland, Baltimore, MD; eSchool of Physiotherapy, Australian Catholic University, Brisbane, QLD, Australia; and fUniversity of the Sunshine Coast, Sippy Downs, QLD, Australia.

Abstract
Objective: To investigate the effectiveness of aquatic exercise in improving lower limb strength in people with musculoskeletal conditions.

Data Sources: A systematic search used 5 databases, including MEDLINE, CINAHL, Embase, SPORTDiscus, and The Cochrane Library.

Study Selection: Randomized controlled trials evaluating aquatic exercise with a resistance training component for adults with musculoskeletal conditions compared with no intervention or land-based exercise were identified. Fifteen studies from the initial yield of 1214 met these criteria.

Data Extraction: Data related to participant demographics, study design, and methods, interventions, and outcomes, including numerical means and SDs, were extracted independently by 2 reviewers.

Data Synthesis: Nine of the 15 studies were of high quality, scoring at least 6 on the Physiotherapy Evidence Database Scale. Limited consideration of the prescription of resistance in the aquatic exercise and application of resistance training principles existed. Fifteen studies from the initial yield of 1214 met these criteria.

Conclusions: It is likely that the inadequate application of resistance in water is a significant contributor to the limited effectiveness of aquatic exercise interventions in improving hip and knee muscle strength in people with musculoskeletal conditions. Future research is needed to quantify resistance with aquatic exercises and to determine if using opportunities for greater resistance in aquatic rehabilitation and appropriate resistance training principles can be more effective in improving muscle strength.

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Growing research evidence supports the value of aquatic exercise in improving function, quality of life or pain in arthritis, low back pain, fibromyalgia, and after orthopedic surgery. In addition, aquatic exercise is strongly recommended in the management of hip and knee arthritis. Aquatic exercise programs may also positively affect exercise compliance more than land-based programs and facilitate high levels of independent commitment after finishing supervised rehabilitation. Preference for water-based rehabilitation or a more enabling, successful exercise environment may contribute to greater compliance.

The properties of water provide unique opportunities for rehabilitation using the hydrostatic and hydrodynamic principles of buoyancy and drag. Buoyancy offloads weight bearing, and hydrostatic pressure leads to compression to assist managing lower limb edema. The offloading, reduced swelling, and warmth of the water may decrease pain and also stiffness. These properties of water may allow people with pain, swelling, leg weakness, or
other limiting comorbid conditions to exercise successfully when this may not be possible on land. Drag can create assistance for movement or resistance for muscle strengthening. There are additional physiological benefits of immersion for cardiopulmonary exercise related to hydrostatic pressure creating central hypervolemia.

Aquatic exercise describes an environment for structured physical activity rather than a type of exercise. This confusion facilitates poor reporting and unclear definitions of the exact type of exercises used in clinical aquatic programs. The inclusion of resistance exercise in therapy programs is supported in many musculoskeletal conditions; however, the most effective type or combination of exercise is currently unknown. Resistance training addresses strength impairments, which is critical because a strong link between muscular force production, particularly in the lower limb, and function exists. The challenges in quantifying load in aquatic exercises are problematic because progressive overload of exercises is of key importance in achieving optimal outcomes related to strength.

Studies using aquatic rehabilitation in musculoskeletal conditions often specify resistance exercise as part of the program and assess strength outcomes. Although there are growing numbers of trials in aquatic exercise, no consensus has been reached related to how effective it is in increasing strength in musculoskeletal conditions. Reviews in hip and knee arthritis and fibromyalgia report limited findings of positive outcomes in improving strength because of small numbers of studies combined in their analysis. Aquatic physiotherapy programs have been criticized for being nonprogressive and low intensity. The effectiveness of aquatic exercise in improving strength needs further comprehensive investigation, particularly related to the link between load, types of exercise, and degree of change in strength outcomes compared with land-based exercise in individuals with musculoskeletal conditions.

It is unclear whether aquatic exercise in musculoskeletal populations is effective in changing strength. The theoretical model of aquatic exercise combining the best features of both isometric and resistance training with variable velocity drag overload leading to improvements in strength has not been thoroughly investigated. This systematic review investigates the effectiveness of aquatic exercise in improving muscular strength, endurance, and power outcomes in the lower limb in musculoskeletal conditions, including arthritis, osteoporosis, fibromyalgia, and after orthopedic surgery, in comparison with no exercise or land-based exercise programs. The secondary aim is to determine the scope of exercises prescribed and the resistance training principles used in these aquatic rehabilitation programs.

Methods

Literature search

A peer-reviewed search strategy was developed after trialing various databases and subject headings related to concepts of aquatic exercise or aquatic rehabilitation and outcomes related to muscular strength, endurance, or power. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines were followed (Appendix 1). A final search of 5 databases, including MEDLINE, CINAHL, SPORTDiscus, Embase, and The Cochrane Library, was conducted from inception until June 2015. A sensitive search strategy was developed using subject heading, title, and/or abstract as applicable, relevant to aquatic exercise or therapy and the outcomes of interest (Appendix 2). Reference lists in the included articles and relevant review articles were checked manually to identify any further articles not found in the systematic database search. The proposed systematic review details were registered in PROSPERO (no. CRD42014015546).

Eligibility criteria

Study selection

Two independent reviewers (S.H. and A.R.) considered titles and abstracts from the search of each database using a standardized checklist of the predetermined inclusion and exclusion criteria, which is subsequently detailed further. Full-article review was the final stage of study selection if the titles and abstracts appeared to fit the criteria. A third reviewer (J.M.) had input in any areas of disagreement.

Types of studies and participants

Randomized controlled studies were included if they investigated musculoskeletal conditions including after orthopedic surgery, were written in English, were in full text in a peer-reviewed journal, and included adults >18 years of age.

Interventions

Studies incorporated one group completing aquatic exercise and a comparison group that consisted either of a no exercise group or a land-based exercise group. The intervention must have been delivered for >6 weeks when potential changes in strength or muscular endurance could be expected, and the aims, hypothesis, or description of the intervention must have included resistance training or strengthening. If the intervention did not specifically describe any strengthening exercises or did not refer to increasing strength in the aims or the hypothesis, then the study was excluded. Exercises delivered in an acute phase or as a hospital inpatient were excluded. Studies with cointerventions were only included if administered equally between the 2 groups, and they therefore could reasonably be expected to influence both groups similarly.

Outcomes

Outcome measures included assessment of lower limb strength (concentric and eccentric isokinetic or isometric resistance tests or repetition maximum [RM] tests), muscle endurance (maximal repetitions to fatigue or holding a position for a specified period of time), and power (tests of speed and resistance primarily involving the lower limb, including vertical jump and stair climbing factoring in body weight). Manual muscle testing as a measure of strength was excluded because the validity is not as robust as for the other strength measures.

Methodologic quality assessment

Each of the 18 studies included in the review was rated on the Physiotherapy Evidence Database Scale. Scores ranged from 0 to 10, with studies achieving a score ≥6 considered high quality. Quality assessment was not part of the inclusion or exclusion criteria for the review but was used to facilitate interpretation of findings.
Aquatic exercise and strength review

Data extraction

Two reviewers (S.H. and B.M.) independently extracted data, including relevant details of the study participants, interventions, and outcomes of interest, with discrepancies discussed until consensus was achieved. The number and characteristics of participants (age, sex, and diagnosis), intervention (duration, frequency, number of weeks, types of exercises, depth and speed of aquatic exercises, load, equipment used, progression of program, and description of the components of the program), and the outcomes of interest at all time points were extracted from each study in the affected limb, if specified, or in both limbs if not specified. Authors were contacted for numerical data if both means and measures of variance were not specified in the article.

Statistical analysis

Standardized mean difference (SMD) using Hedge’s g and 95% confidence intervals (CIs) were calculated using outcome scores measured at the final assessment after the intervention. In one study, the final outcome data were not available; therefore, the SMD of the change score was calculated and indicated in subsequent analysis. Outcome scores representing lower limb muscle strength, muscular endurance, and power were included in the analysis. Muscle strength testing using concentric isokinetic dynamometry at the slowest speed was preferentially included in analysis, but where these were not available, isometric strength outcomes were included. Where necessary, SDs were calculated from CIs using a t distribution, as recommended for smaller sample sizes of <60 in each group. The means and SDs of data for subgroups (eg, sex) were collapsed using formulae for the weighted mean and square root of the pooled variance. If data existed for both right and left legs and the affected limb was not specified, or if both sides may have been affected, then the side with the most conservative effect (smallest) size was included in the review. Effect size thresholds were classified as an SMD of small (0.2), medium (0.5), or large (0.8), with nonsignificant results indicated by a 95% CI that included zero.

Meta-analysis

Meta-analysis of the strength outcomes were performed if ≥2 studies reported on the same outcome. A random effects model was used to estimate the average effect of the intervention. The random effects model was chosen in consideration of the clinical and methodological diversity among studies. Studies were subgrouped in the meta-analysis according to participant diagnosis of arthritis, fibromyalgia, osteoporosis, postoperative total knee joint replacement, or anterior cruciate reconstruction. Statistical heterogeneity was considered important if I² >40%. The quality of evidence in each meta-analysis was evaluated using the Grades of Research, Assessment, Development and Evaluation approach. Each meta-analysis was assessed on limitations in design and implementation, inconsistency, indirectness, imprecision, and publication bias. This is outlined in appendix 3.

Results

Search yield

Fifteen studies were included in the review after an initial yield of 1214 potential studies from the electronic search (fig 1).

Description of included studies

Study participant numbers varied from 20 to 312, with 1042 participants in total in the review (table 1). Studies investigated participants with arthritis, including hip and/or knee osteoarthritis, osteoarthritis or rheumatoid arthritis, after knee arthroplasty or anterior cruciate ligament reconstruction, fibromyalgia, or osteoporosis. Thirteen studies included a nonintervention group that did not participate in exercise as a comparator, and 6 studies included a land exercise group. Exercise intervention varied from 30 to 70 minutes, 2 to 3 times per week, from 6 to 52 weeks. The mean aquatic exercise intervention involved therapy for 48 minutes per session, 2.6 times per week over 15.8 weeks.

Methodologic quality

From a maximum score of 10, the number of criteria satisfied by the included studies ranged from 4 to 8 (table 2). Nine of the 15 studies were consistent with high quality, scoring ≥6.

Scope of aquatic intervention: program components and exercises

In describing their programs, 13 of the 15 studies specified resistance or strengthening exercises were included in the program. 1 additional study hypothesized the program would increase lower limb strength, and 1 additional study described muscle strengthening as a goal of the section described as conditioning exercises. Ten studies clearly described a separate component of strengthening exercises.

Content of the aquatic programs varied and included functional exercises (eg, walking, open kinetic chain, closed kinetic chain, plyometric exercises). The exercises involving the lower body are detailed in supplemental table S1 (available online only at http://www.archives-pmr.org/).

Five studies detailed each exercise included in their aquatic program. From the studies describing individual exercises, 2 studies included exercises with the hip or knee moving in an open kinetic chain without any closed kinetic chain exercises included. One study specified closed kinetic chain exercise on a single leg. Plyometric exercises (eg, jumping, hopping) were specified as part of 1 study. In an additional 3 studies, the plyometric exercises were not included specifically to target strength but were included in the...
Table 1  Overview of studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Diagnosis</th>
<th>Overall Participants in the Study</th>
<th>Aquatic Exercise Group</th>
<th>No Exercise Group</th>
<th>Land Exercise Group</th>
<th>Exercise Intervention</th>
<th>Compliance</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Males/ Females Mean Age ± SD</td>
<td>Males/ Females Mean Age ± SD</td>
<td>Males/ Females Mean Age ± SD</td>
<td>Length of Sessions (min)</td>
<td>Frequency of Sessions (per wk)</td>
<td>Duration of Sessions (wk)</td>
<td>Aquatic Exercise (%)</td>
</tr>
<tr>
<td>Cochrane et al</td>
<td>Hip and/or knee OA</td>
<td>312 56/97 69.9 ± 6.8</td>
<td>60/99 69.6 ± 6.3</td>
<td>NA NA</td>
<td>60</td>
<td>At least 2</td>
<td>42—52</td>
<td>59 NA</td>
</tr>
<tr>
<td>Foley et al</td>
<td>Hip and/or knee OA</td>
<td>105 20/15 73 ± 8.2</td>
<td>15/20 69.8 ± 9</td>
<td>15/17 69.8 ± 9.2</td>
<td>30</td>
<td>3</td>
<td>6</td>
<td>84 75</td>
</tr>
<tr>
<td>Hinman et al</td>
<td>Hip and/or knee OA</td>
<td>71 12/24 63.3 ± 9.5</td>
<td>11/24 61.5 ± 7.8</td>
<td>NA NA</td>
<td>45—60</td>
<td>2</td>
<td>6</td>
<td>&gt;83 NA</td>
</tr>
<tr>
<td>Wang et al</td>
<td>Hip and/or knee OA</td>
<td>42 4/16 69.3 ± 13.3</td>
<td>2/16 62.7 ± 10.7</td>
<td>NA NA</td>
<td>50</td>
<td>3</td>
<td>12</td>
<td>82 NA</td>
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<tr>
<td>Lim et al</td>
<td>Knee OA</td>
<td>75 3/23 65.7 ± 8.9</td>
<td>3/21 HEP</td>
<td>63.3 ± 5.3</td>
<td>4/21 67.7 ± 7.7</td>
<td>40</td>
<td>3</td>
<td>8 &gt;67 &gt;67</td>
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<tr>
<td>Lund et al</td>
<td>Knee OA</td>
<td>79 5/22 65 ± 12.6</td>
<td>9/18 70 ± 9.9</td>
<td>3/22 68.9 ± 5.5</td>
<td>50</td>
<td>2</td>
<td>8</td>
<td>92 85</td>
</tr>
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<td>Suomi and</td>
<td>OA or RA</td>
<td>30 0/17 59.8 (range, 45—67)</td>
<td>0/10 54.4 (range, 48—67)</td>
<td>NA NA</td>
<td>45</td>
<td>3</td>
<td>6</td>
<td>82 NA</td>
</tr>
<tr>
<td>Suomi and</td>
<td>OA or RA</td>
<td>32 2/8 68.0 ± 6.8</td>
<td>2/8 68.3 ± 6.2</td>
<td>2/8 64.2 ± 3.3</td>
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<td>2</td>
<td>8</td>
<td>79 90</td>
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<tr>
<td>Rintala et al</td>
<td>RA</td>
<td>34 3/15 48 ± 10</td>
<td>2/14 48 ± 10</td>
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<td>45—60</td>
<td>2</td>
<td>12</td>
<td>91 NA</td>
</tr>
<tr>
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<td>TKA</td>
<td>50 10/16 66.2 ± 6.3</td>
<td>10/14 65.7 ± 6.0</td>
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<td>43—53</td>
<td>2</td>
<td>12</td>
<td>98 NA</td>
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<tr>
<td>Tovin et al</td>
<td>ACLR</td>
<td>20 6/4 29 ± 7.8</td>
<td>NA NA</td>
<td>8/2 29 ± 7.8</td>
<td>Unclear</td>
<td>3</td>
<td>7</td>
<td>NR NR</td>
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<tr>
<td>Gusi et al</td>
<td>FM</td>
<td>35 0/18 51 ± 10</td>
<td>0/17 51 ± 9</td>
<td>NA NA</td>
<td>60</td>
<td>3</td>
<td>12</td>
<td>&gt;94 NA</td>
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<td>Munguia-Izquierdo et al</td>
<td>FM</td>
<td>60 0/34 50 ± 7</td>
<td>0/24 46 ± 8</td>
<td>NA NA</td>
<td>50—70</td>
<td>3</td>
<td>16</td>
<td>88 NA</td>
</tr>
</tbody>
</table>

(continued on next page)
aerobic component of the aquatic program, and a further study included them during warm-up. Therapist-resisted strengthening techniques were applied in 1 study.

### Intervention: resistance training principles

#### Assessment for prescription of resistance or intensity of exercise: Land

Four of the land exercise groups prescribed resistance related to an RM, either as a percentage of 1RM, ranging from 40% to 60% or 70% to 80%, or related to 10RM. One study used maximal heart rate >65% to prescribe intensity of the exercise. In these studies, both ratings of perceived exertion and heart rate were used throughout all components of the program except the warm-up and cooldown.

#### Description of specific resistance: Land

Resistance was described using an RM, either as a percentage of 1RM ranging from 40% to 60% or 70% to 80% or related to 10RM in 4 of the 6 land programs. One land exercise group designated a specified weight of 4.5kg of resistance in lower body exercise.

#### Progression of resistance exercise: Land exercise programs

Three studies progressed the land lower limb exercises with increased resistance, and 1 study progressed resistance in trunk exercise. Volume of land exercises were increased in 3 studies.

#### Use of equipment for resistance: Land

Five of the 6 programs with a land group used equipment for resistance.
<table>
<thead>
<tr>
<th>Study</th>
<th>Diagnosis</th>
<th>Eligibility Criteria Are Specified</th>
<th>Random Allocation*</th>
<th>Concealed Allocation*</th>
<th>Baseline Comparability for Prognostic Indicators*</th>
<th>Blinded Therapists Who Administered the Treatment*</th>
<th>Blinded Assessor Measuring At Least 1 Key Outcome*</th>
<th>Adequate Follow-Up*</th>
<th>Intention to Treat Analysis*</th>
<th>Between-Group Comparisons in At Least 1 Key Outcome*</th>
<th>Point Estimates and Variability in At Least 1 Key Outcome*</th>
<th>PEDro Score (rated out of 10)</th>
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<tbody>
<tr>
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<td>Hip and/or knee OA</td>
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<td>Y</td>
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<td>Lim et al51</td>
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<td>N</td>
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<td>Y</td>
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<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>6</td>
</tr>
</tbody>
</table>

Abbreviations: ACLR, anterior cruciate ligament reconstruction; FM, fibromyalgia; N, no; OA, osteoarthritis; OP, osteoporosis; PEDro, Physiotherapy Evidence Database Scale; RA, rheumatoid arthritis; TKA, total knee arthroplasty; Y, yes.

* Items contribute to final score.
Use of equipment for resistance: Aquatic

Seven of the 15 studies used equipment for resistance in the water (eg, steps, floats, fins). Studies of this kind are described without a clear equipment purpose and exact usage.

Measures of strength, endurance, or power

Isometric or isokinetic strength measurement constituted the most common outcome in the review with 13 of the 15 studies measuring in either the hip abductors or the knee extensors or flexors. All isokinetic testing was concentric except in 2 studies that also measured eccentric isokinetic strength of the knee extensors. Using the more conservative effect size when strength was tested bilaterally may underrepresent some studies that demonstrated greater effect on 1 leg. 

Hip strength

Four studies in participants with arthritis were included in the meta-analysis of hip abductor strength. Low-quality evidence showed that there were no differences in hip abductor strength between aquatic exercise and a no exercise group (pooled SMD, .28; 95% CI, −.04 to .59; $I^2 = 0\%$) (fig 2).

Isometric strength testing of the hip flexors, extendors, and adductors was assessed in a single study comparing aquatic exercise and no exercise, and no differences between groups were reported (single SMD: hip flexors SMD, .26; 95% CI, −.38 to .90; hip extendors SMD, 0.56; 95% CI, −.09 to 1.21; hip adductors SMD, 0.55; 95% CI, −.10 to 1.20).

A single study found the same effect between land and aquatic exercise for hip abductor strength (single effect size: SMD, .00; 95% CI, −.88 to .88).

Knee strength

Strength of the knee extensors was compared between aquatic exercise and a no exercise group in 9 studies. There was low-quality evidence that showed no difference between average effect for improvements in knee extensor strength with aquatic exercise compared with no exercise (fig 3A) (pooled SMD, .18; 95% CI, −.03 to .40; $I^2 = 35\%$).

When aquatic exercise was compared with land-based exercise, low-quality evidence in the meta-analysis showed no difference in effect in knee extensor strength (fig 3B) (pooled SMD, −.24; 95% CI, −.49 to .02; $I^2 = 0\%$).

For knee flexor strength, the quality of evidence was very low and showed no difference between aquatic exercise and the no exercise groups (fig 4A) (pooled SMD, .34; 95% CI, −.26 to .94). There was significant heterogeneity detected between the studies ($I^2 = 60\%$).

Muscular endurance

Muscular endurance of the lower limb was measured in 2 studies using maximum number of squats or sit to stand. Low-quality evidence showed no differences between aquatic exercise and a no exercise group for lower limb endurance (fig 5) (pooled SMD, .35; 95% CI, −.06 to .77; $I^2 = 0\%$).

Discussion

This review demonstrated very low— or low-quality evidence, demonstrating a lack of effectiveness of aquatic exercise in improving lower limb strength and endurance in people with musculoskeletal disease. There was a lack of effectiveness regardless of whether the aquatic exercise was compared with a no exercise group or land exercise. The reduced effect of aquatic exercise in both comparisons is likely to be related to insufficient resistance in the strengthening exercises to stimulate strength changes in hip and knee muscles. Clearer prescription of load using hydrostatic, hydrodynamic, and resistance training principles may lead to more effective changes in strength in aquatic rehabilitation. Limited knowledge in the amount of resistance or force in specific aquatic exercises potentially contributed to the variability in strengthening exercise prescription.

The lack of effectiveness may relate to limited consideration in the prescription of resistance during aquatic strengthening exercises. Resistance levels in strengthening exercises for people with arthritis, people with osteoporosis, or older adults are recommended at 50% to 80% of 1RM or 12RM to 15RM to stimulate increased muscle strength. Although 1 RM to assess and then prescribe strengthening exercise was included in some of the land-based programs, no aquatic programs assessed participant strength to determine the appropriate resistance level. Rating of perceived exertion was used in some of the aquatic programs to monitor or progress exercise intensity; however, it was unclear if the prescribed intensity level was sufficient during the strengthening exercises. The criticism of insufficient load in some musculoskeletal aquatic exercise programs as too low for strength training appears justified and must be addressed in aquatic rehabilitation in the future.

Land-based exercise programs have also been identified as being of insufficient stimulus or not targeted enough for effective strength gains in musculoskeletal rehabilitation. Higher-intensity resistance training may lead to greater and more sustained benefits in knee strength when compared with lower-intensity resistance programs in knee osteoarthritis; however, further investigation into the most effective type of exercise in long-term follow-up is needed. Aquatic exercise may result in similar outcomes to land-based training in improving knee strength with the benefit of reduced load on joints, but the limitation of the environment being less functional. Findings of similar effectiveness for improving knee strength between land and aquatic exercise in this review may relate to both environments requiring more targeted and greater resistance in programs and further investigation for optimal program content.

Unlike the reviewed studies, greater resistance during aquatic exercise is clinically possible and necessary. Greater resistance in aquatic exercise may be achieved by reducing the buoyancy effect by exercising in shallower depths, particularly with single-leg closed kinetic chain exercise. Drag resistance can be increased with faster or maximal speeds of movement or...
Fig 3  (A) Meta-analysis of knee extensor strength: aquatic exercise versus no exercise. (B) Meta-analysis of knee extensor strength: aquatic exercise versus land exercise. Abbreviations: ACLR, anterior cruciate ligament reconstruction; OA, osteoarthritis; OP, osteoporosis; Std., standard; TKA, total knee arthroplasty. *After the removal of dropouts, groups could not be confirmed as similar. †Change scores used.

### Table 1: Meta-analysis of knee extensor strength

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Aquatic Exercise</th>
<th>No exercise control</th>
<th>Std. Mean Difference IV, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Total</td>
</tr>
<tr>
<td>Hinman 2007 (isometric)</td>
<td>22.2</td>
<td>8.5</td>
<td>36</td>
</tr>
<tr>
<td>Suomi 1997 (isometric)</td>
<td>73.7</td>
<td>15.9</td>
<td>17</td>
</tr>
<tr>
<td>Suomi 2003 (isometric)</td>
<td>72.9</td>
<td>23.9</td>
<td>10</td>
</tr>
<tr>
<td>Wang 2006 (isometric)</td>
<td>12.6</td>
<td>2.7</td>
<td>20</td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>83</strong></td>
<td><strong>73</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 0.00; Chi² = 1.29, df = 3 (P = 0.73); I² = 0%
Test for overall effect: Z = 1.70 (P = 0.09)
Fig 4  (A) Meta-analysis of knee flexor strength: aquatic exercise versus no exercise. (B) Meta-analysis knee flexor strength: aquatic exercise versus land exercise. Abbreviations: ACLR, anterior cruciate ligament reconstruction; OA, osteoarthritis; Std., standard; TKA, total knee arthroplasty. *After the removal of dropouts, groups could not be confirmed as similar. †Change scores used.

Fig 5  Lower limb endurance: aquatic exercise versus no exercise. Abbreviation: Std., standard.
larger surface area using equipment. Underwater jets can also be used to increase resistance and intensity of exercise. There were only a few aquatic programs included in this review using these concepts. Aquatic plyometric exercise is another opportunity for higher levels of resistance, particularly in the push off phase. It is as effective in healthy young populations as land-based plyometric exercise and could be used more in aquatic musculoskeletal rehabilitation. In the reviewed programs, plyometric exercise occurred more often in the aquatic exercise aerobic component rather than in the strengthening component.

In addition to a limited consideration of resistance training principles, a lack of consensus existed about which exercises to include in aquatic strengthening programs. This finding may relate to the limited empirical research in understanding specific exercises and resistance involved in the aquatic environment. Only a few studies investigated resistance or forces in exercises used in aquatic rehabilitation, and none included people with musculoskeletal conditions. Contrary to other systematic review findings of pain, function, and quality of life outcomes, closed kinetic chain exercises were not commonly used in the aquatic programs in this review. More research is required to fully understand both how the aquatic environment influences movement and resistance and also the association with land-based strengths changes, for people with musculoskeletal conditions.

Study limitations

There are several limitations in this review and meta-analysis that must be considered. First, a single measure of strength was selected to represent data from each study in the meta-analysis. This could have omitted the opportunity to find differences between groups in measures of strength not selected for analysis. It was decided to include only isokinetic tests at the slowest speed because these testing conditions are the most reliable; however, specific analysis of differences in strength at higher speeds of contraction is warranted as the body of research in this area grows. Second, in some studies it was not clear which data related to the affected limb or if both limbs were affected, and a decision was made to include the most conservative effect size. Therefore, the findings of this study may underrepresent potential differences in strength between groups.

Future research in musculoskeletal aquatic therapy is needed (1) to quantify resistance with aquatic exercises; (2) to provide greater clarity in the aims, type, and documentation of aquatic exercises and resistance training principles in randomised controlled trials to facilitate greater improvements in muscle strength; and (3) to determine which patient characteristics (eg, pain or functional level, obesity, disease severity) may be most responsive to aquatic therapy.

Conclusions

In this review it appears inadequate resistance application is a significant contributor to limited effectiveness in aquatic exercise in increasing hip and knee muscle strength in people with musculoskeletal conditions. To better understand the potential therapeutic benefit of aquatic strengthening exercise, consideration of required resistance assessment and greater levels of resistance application in water should be a focus for future research.
Risk of bias across studies: specified any assessment of risk of bias that may affect the cumulative evidence.
Additional analyses: not applicable.

Results

Study selection: numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, plus a flow diagram (see fig 1).
Study characteristics: presented.
Risk of bias within studies: presented.
Results of individual studies: presented (see table 1).
Synthesis of results: presented results of each meta-analysis done, including confidence intervals and measures of consistency.
Risk of bias across studies: presented results of any assessment of risk of bias across studies.
Additional analysis: give results of additional analyses, if done (eg, sensitivity or subgroup analyses, meta-regression: not applicable).

Discussion

Summary of evidence: summarized the main findings.
Limitations: discussed limitations.
Conclusions: provide a general interpretation of the results in the context of other evidence and implications for future research.

Funding

Funding: describe sources: not applicable.

Appendix 2 Search Strategy

Search terms

Intervention: aquatic exercise program, hydrotherapy, aquatic exercise*, water exercise*, aquatic therapy*, aquatic rehab*, water aerobic*, aquarobic*, aquatic physiotherapy, aquatic physical therapy, aquatic plyometric*, water plyometric*, aquatic resistance, deep water running
Outcomes: strength, power, endurance, strength*, endurance, power, maxim* voluntary contraction, repetition maximum, manual muscle test, dynamomet*, force*, torque*, isokinetic, isometric, exercise test*, vertical jump

Additional subject or Medical Subject Headings used across specific databases

MEDLINE complete (EBSCO) and The Cochrane Library
Intervention: Hydrotherapy
Outcomes: Muscle strength; Muscle strength dynamometer; Torque; Exercise test; Muscle strength dynamometer; Muscle contraction

CINAHL complete (EBSCO)
Intervention: Aquatic exercises; Hydrotherapy
Outcomes: Muscle strength; Exercise test, muscular (includes dynamometry); Torque; Physical endurance; Muscle contraction

SPORTDiscus (EBSCO)
Intervention: Hydrotherapy; Aquatic exercises
Outcomes: Muscle strength; Torque; Exercise tests; Vertical jump

Embase (Ovid)
Intervention: Hydrotherapy; Aquatic exercises
Outcomes: Muscle strength; Torque; Endurance; Exercise test; Dynamometer; Dynamometry; Muscle force; Muscle contraction

Appendix 3 Grades of Research, Assessment, Development, and Evaluation Quality of Evidence for the Meta-Analyses

The quality of evidence in each meta-analysis was evaluated using the Grades of Research, Assessment, Development, and Evaluation approach. Each meta-analysis started as high quality related to inclusion of randomized trials. It was then graded on the following:

1. Limitations in design and implementation (downgrade if most of included studies are at risk of bias in the Physiotherapy Evidence Database Scale assessment or related to compliance).
2. Inconsistency (downgrade if point estimates vary widely, CI shows minimal or no overlap, P value low, or I² statistic >50%).
3. Indirectness (no downgrade applied because all comparisons were direct).
4. Imprecision (downgrade applied because all comparisons were indirect).
5. Publication bias (downgrade if funnel plots are asymmetrical on visual inspection).
References


Aquatic exercise and strength review


