

Aquatic exercise for the treatment of knee and hip osteoarthritis

Bartels, Else Marie; Juhl, Carsten B; Christensen, Robin; Hagen, Kåre Birger; Danneskiold-Samsøe, Bente; Dagfinrud, Hanne; Lund, Hans

Published in:
Cochrane Database of Systematic Reviews

DOI:
[10.1002/14651858.CD005523.pub3](https://doi.org/10.1002/14651858.CD005523.pub3)

Publication date:
2016

Document version
Final published version

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Citation for pulished version (APA):
Bartels, E. M., Juhl, C. B., Christensen, R., Hagen, K. B., Danneskiold-Samsøe, B., Dagfinrud, H., & Lund, H. (2016). Aquatic exercise for the treatment of knee and hip osteoarthritis. *Cochrane Database of Systematic Reviews*, (3), [CD005523]. <https://doi.org/10.1002/14651858.CD005523.pub3>

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Cochrane Database of Systematic Reviews 2016, Issue 3. Art. No.: CD005523.

DOI: 10.1002/14651858.CD005523.pub3.

www.cochranelibrary.com

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[Intervention Review]

Aquatic exercise for the treatment of knee and hip osteoarthritis

Else Marie Bartels¹, Carsten B Juhl², Robin Christensen³, Kåre Birger Hagen⁴, Bente Danneskiold-Samsøe⁵, Hanne Dagfinrud⁴, Hans Lund^{6,7}

¹The Parker Institute, Copenhagen University Hospital, Bispebjerg og Frederiksberg, Frederiksberg, Denmark. ²SEARCH (Research group for synthesis of evidence and research), Research Unit for Musculoskeletal Function and Physiotherapy, Institute of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense M, Denmark. ³Musculoskeletal Statistics Unit, The Parker Institute, Copenhagen University Hospital, Bispebjerg og Frederiksberg, Copenhagen, Denmark. ⁴National Advisory Unit for Rehabilitation in Rheumatology, Diakonhjemmet Hospital, Oslo, Norway. ⁵The Parker Institute, Frederiksberg Hospital, Frederiksberg, Denmark. ⁶SEARCH (Research group for synthesis of evidence and research), Research Unit for Musculoskeletal Function and Physiotherapy, Institute of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense M, Denmark. ⁷Center for Evidence-Based Practice, Bergen University College, Bergen, Norway

Contact address: Hans Lund, SEARCH (Research group for synthesis of evidence and research), Research Unit for Musculoskeletal Function and Physiotherapy, Institute of Sports Science and Clinical Biomechanics, University of Southern Denmark, Campusvej 55, Odense M, DK-5230, Denmark. hlund@health.sdu.dk.

Editorial group: Cochrane Musculoskeletal Group.

Publication status and date: New search for studies and content updated (no change to conclusions), published in Issue 3, 2016.

Review content assessed as up-to-date: 28 April 2015.

Citation: Bartels EM, Juhl CB, Christensen R, Hagen KB, Danneskiold-Samsøe B, Dagfinrud H, Lund H. Aquatic exercise for the treatment of knee and hip osteoarthritis. *Cochrane Database of Systematic Reviews* 2016, Issue 3. Art. No.: CD005523. DOI: 10.1002/14651858.CD005523.pub3.

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ABSTRACT

Background

Osteoarthritis is a chronic disease characterized by joint pain, tenderness, and limitation of movement. At present, no cure is available. Thus only treatment of the person's symptoms and treatment to prevent further development of the disease are possible. Clinical trials indicate that aquatic exercise may have advantages for people with osteoarthritis. This is an update of a published Cochrane review.

Objectives

To evaluate the effects of aquatic exercise for people with knee or hip osteoarthritis, or both, compared to no intervention.

Search methods

We searched the following databases up to 28 April 2015: the Cochrane Central Register of Controlled Trials (CENTRAL; the Cochrane Library Issue 1, 2014), MEDLINE (from 1949), EMBASE (from 1980), CINAHL (from 1982), PEDro (Physiotherapy Evidence Database), and Web of Science (from 1945). There was no language restriction.

Selection criteria

Randomized controlled clinical trials of aquatic exercise compared to a control group (e.g. usual care, education, social attention, telephone call, waiting list for surgery) of participants with knee or hip osteoarthritis.

Aquatic exercise for the treatment of knee and hip osteoarthritis (Review)

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Data collection and analysis

Two review authors independently selected trials for inclusion, extracted data and assessed risk of bias of the included trials. We analysed the pooled results using standardized mean difference (SMD) values.

Main results

Nine new trials met the inclusion criteria and we excluded two earlier included trials. Thus the number of participants increased from 800 to 1190 and the number of included trials increased from six to 13. Most participants were female (75%), with an average age of 68 years and a body mass index (BMI) of 29.4. Osteoarthritis duration was 6.7 years, with a great variation of the included participants. The mean aquatic exercise duration was 12 weeks. We found 12 trials at low to unclear risk of bias for all domains except blinding of participants and personnel. They showed that aquatic exercise caused a small short term improvement compared to control in pain (SMD -0.31 , 95% CI -0.47 to -0.15 ; 12 trials, 1076 participants) and disability (SMD -0.32 , 95% CI -0.47 to -0.17 ; 12 trials, 1059 participants). Ten trials showed a small effect on quality of life (QoL) (SMD -0.25 , 95% CI -0.49 to -0.01 ; 10 trials, 971 participants). These effects on pain and disability correspond to a five point lower (95% CI three to eight points lower) score on mean pain and mean disability compared to the control group (scale 0 to 100), and a seven point higher (95% CI 0 to 13 points higher) score on mean QoL compared with control group (scale 0 to 100). No included trials performed a radiographic evaluation. No serious adverse events were reported in the included trials with relation to aquatic exercise.

Authors' conclusions

There is moderate quality evidence that aquatic exercise may have small, short-term, and clinically relevant effects on patient-reported pain, disability, and QoL in people with knee and hip OA. The conclusions of this review update does not change those of the previous published version of this Cochrane review.

PLAIN LANGUAGE SUMMARY

Aquatic exercise for people with osteoarthritis in the knee or hip

Review question

What are the effects of aquatic exercise interventions in the treatment of people with knee and hip osteoarthritis (OA)?

Background: what is osteoarthritis of the hip and knee, and what is aquatic exercise?

Osteoarthritis is a chronic disease characterized by joint pain, tenderness, and limitation of movement. At present no cure is available. Thus only treatment of the person's symptoms and treatment to prevent further development of the disease are possible. Aquatic exercise is physical exercises taking place while the participant are immersed in water, typically water with a temperature between 32°C to 36°C. This is a review update of a published Cochrane review, and presents results from research concerning the effect of aquatic exercise for treating people with the knee and hip osteoarthritis.

Study characteristics

In this summary of this Cochrane review update we present what we know from research about the effects of aquatic exercise for people with osteoarthritis of the knee and hip. After searching for all relevant trials up to 28 April 2015, we included nine new trials since the last version of the Cochrane review. In total we included 13 trials (1190 participants). Most of these trials included participants with mild to moderate symptomatic knee or hip osteoarthritis.

Key results

Aquatic exercise for a mixed group of people with knee and hip osteoarthritis probably improves pain, disability slightly, and may improve quality of life slightly immediately after completion of a treatment course (up to 12 weeks of aquatic exercise). This review update does not change the conclusions of the previous published version of this Cochrane review.

Pain [lower score is better]

People who completed an aquatic exercise programme rated their pain as five points lower (three to eight points lower) on a 0 to 100 scale at the end of aquatic exercise compared with people who did not receive aquatic exercise (5% absolute improvement)

People who completed an exercise program rated their pain to be 41 points on a scale of 0 to 100

People in the control group rated their pain to be 46 points on a scale of 0 to 100.

Disability [lower score is better]

People who completed an aquatic exercise programme rated their disability as five points lower (three to eight points lower) on a 0 to 100 scale at the end of aquatic exercise compared with people who did not receive aquatic exercise (5% absolute improvement)

People who completed an exercise program rated their disability to be 39 points on a scale of 0 to 100

People in the control group rated their disability to be 44 points on a scale of 0 to 100

Quality of life [higher score is better]

People who completed an aquatic exercise programme rated their quality of life as seven points higher (0 to 13 points higher) on a 0 to 100 scale at the end of aquatic exercise compared with people who did not receive aquatic exercise (13% absolute improvement)

People who completed an exercise program rated their quality of life to be 57 points on a scale of 0 to 100

People in the control group rated their quality of life to be 50 points on a scale of 0 to 100

X-rays of the joints - no studies measured this outcome

Withdrawals from the study

3 more people out of 100 dropped out of the aquatic exercise programme (3% absolute increase)

18 people out of 100 in the aquatic exercise group dropped out of the exercise programme

15 people out of 100 dropped out of the control group

Serious adverse events

No serious side effects were reported with relation to participating in aquatic exercise

Quality of evidence

Moderate quality evidence shows that among people with hip and knee osteoarthritis, aquatic exercise may reduce pain and disability, and increase quality of life immediately after the end of the programme of treatment. Further research may change these results.

SUMMARY OF FINDINGS FOR THE MAIN COMPARISON *[Explanation]*

Aquatic exercise for treating people with knee and hip osteoarthritis						
<p>Participants: people with knee and hip osteoarthritis. Settings: outpatient. Intervention: aquatic exercise programme. Comparison: control treatment (e.g. usual care, information).</p>						
Outcomes	Illustrative comparative risks (95% CI)		Effect size (95% CI)	Number of participants (trials)	Quality of the evidence (GRADE)	Comments
	Assumed effect	Corresponding effect				
	Control treatment	Exercise therapy				
<p>Pain on a 0 to 100 scale. Various pain scales. (lower score is better)</p>	<p>Weighted mean pain in control groups was 46 points (95% CI 32 points up to 73) on a 0 to 100 scale</p>	<p>The mean pain in the aquatic exercise groups was 5 points lower (95% CI 3 to 8 points lower) compared with the control group.¹</p>	<p>SMD -0.31 (95% CI -0.47 to -0.15).</p>	<p>1135 (12 trials)</p>	<p>⊕⊕⊕○² moderate</p>	<p>Absolute change: 5% (95% CI 3% to 8%) Relative change: 9.0% (95% CI 4.3% to 13.6%).¹ NNTB: 9 (95% CI 6 to 16).³</p>
<p>Disability on a 0 to 100 scale. Various disability scales (lower score is better)</p>	<p>Weighted mean disability in control groups was 44 points (95% CI 33 points up to 63) on a 0 to 100 scale</p>	<p>The mean disability in the aquatic exercise groups was 5 points lower (95% CI 3 to 8 points lower) compared with control group.¹</p>	<p>SMD -0.32 (95% CI -0.47 to -0.17).</p>	<p>1116 (12 trials)</p>	<p>⊕⊕⊕○² moderate</p>	<p>Absolute change: 5% (95% CI 3% to 8%) Relative change: 12.4% (95% CI 6.6% to 18.2%) NNTB: 11 (95% CI 8 to 19).³</p>
<p>Quality of life on a 0 to 100 scale. Various quality of life scales. (higher score is better)</p>	<p>Weighted mean quality of life in control groups was 50 points (95% CI 24 points up to 67 points) on a 0 to 100 scale</p>	<p>The mean quality of life in the aquatic exercise groups was 7 points higher (95% CI 0 to 13 points higher) compared with the control group.⁴</p>	<p>SMD -0.25 (95% CI -0.49 to -0.01).</p>	<p>1027 (10 trials)</p>	<p>⊕⊕⊕○² moderate</p>	<p>Absolute change: 7% (0 to 13%) Relative change 13.2% (95% CI 0.5% to 25.9%). NNTB: 13 (95% CI 8 to 288).⁵</p>

Withdrawals	15 per 100	18 per 100 (14 to 23)	RR 1.25 (95% CI 0.98 to 1.60)	1190 (13 trials)	⊕⊕⊕ ² moderate	Absolute change: 3% (95% CI -1% to 9%) Relative percent change 22% (95% CI 6% fewer withdrawals % to 57 more withdrawals%) NNTH: 31 (95% CI 14 to) ⁶
Radiographic evaluation	see comments	see comments	see comments	see comments	see comments	The included trials did not perform any radiographic evaluation
Short term serious adverse effects from trials	see comments	see comments	see comments	see comments	see comments	None reported.
Long term adverse effects or toxicity from observational studies	see comments	see comments	see comments	see comments	see comments	None reported.

¹Estimated from the SMD into percent improvement based on [Bliddal 2009](#).

²Downgraded by one level due to high risk of bias.

³We estimated the NNTB (Number Needed to Treat for an additional beneficial outcome) from the OR. We transformed the SMD value to the OR using the equation of [Chinn 2000](#). We set the patient expected event rate (PEER) to 0.4 for pain and to 0.26 for disability, based on [Tubach 2005](#).

⁴The SD value from the largest trial ([Cochrane 2005](#); SD in control group = 27.17) was multiplied with the SMD value of QoL (SMD -0.25, 95% CI -0.49 to -0.01)

⁵We estimated the NNTB from the OR. We transformed the SMD value to the OR using the equation of [Chinn 2000](#). Since we assumed a strong relation between QoL and disability, we chose the PEER of 0.26 for disability based on [Tubach 2005](#).

⁶We estimated the NNTH (Number Needed to Treat for an additional harmful outcome) from the RR, where the assumed control risk is the number of withdrawals in the control group

GRADE Working Group grades of evidence

High quality: further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: we are very uncertain about the estimate.

Abbreviations: SMD: standardized mean difference; OR: odds ratio; CI: confidence interval; PEER: patient expected event rate; SD: standard deviation; QoL: quality of life.

BACKGROUND

Osteoarthritis (OA) is a chronic disease characterized by joint pain, tenderness, limitation of movement, crepitus, occasional effusion, and variable degrees of local inflammation. The disease process affects the articular cartilage and also involves the entire joint, including the subchondral bone, ligaments, capsule, synovial membrane, and periarticular muscles (Flores 2003). OA occurs most frequently in people's hands, hips, knees, back, and neck (Felson 2003). The characteristics of the disease are thickening of the joint capsule, progressive cartilage loss, and osteophyte formation, leading to disability (Oliveria 1995; Sowers 2000). Epidemiological studies show that OA accounts for more sick leave and disability than the general population (Cross 2014; Hubertsson 2013), and more trouble in walking and climbing stairs than any other musculoskeletal disease (Guccione 1994). At present, only treatment of the symptoms and treatment to prevent further development of the disease are available. Knee and hip OA are widespread diseases seen in up to 6% of the general population aged 30 and over (Felson 1998). The prevalence of OA increases with age, and prevalence will probably increase in the future due to the growing group of elderly people (Cross 2014).

The aim of exercise therapy for people with OA is to improve their strength and control over the knee joint in order to improve sensorimotor control and achieve compensatory functional stability (Ageberg 2015). This may be achieved by the following changes: increased muscle strength, improved balance and coordination of movements, and improved joint mobility (Ageberg 2015; Hurley 2003). Increased muscle strength in people with OA is correlated with the person's functional level (Gur 2002).

Over the years aquatic exercise has been known as pool therapy, hydrotherapy, or balneotherapy, and describes exercise performed in water. Most often the water is heated to 32°C to 36°C. Since the main aim of physical therapy for people with OA is to diminish pain and improve their physical ability, we will only include trials in this Cochrane review that applied an aquatic exercise programme to participants with OA in the knee or hip joint, or both.

Aquatic exercise may be advantageous for people with OA. When the element of hot water is included, it is thought to reduce pain sensation, reduce stiffness of the muscular-skeletal system, and to cause muscle relaxation in people with arthritis (Elkayam 1991). Aquatic exercise may therefore be more beneficial as initial exercise therapy for people with OA than similar training on land.

OBJECTIVES

To evaluate the effects of aquatic exercise for people with knee or hip OA, or both, compared to no intervention.

METHODS

Criteria for considering studies for this review

Types of studies

We included randomized controlled trials (RCTs) concerning treatment of knee or hip osteoarthritis (OA), or both, with aquatic exercise compared to a control group (e.g. usual care, education, social attention, telephone call, or waiting list for surgery).

Types of participants

We included participants with OA in either one and/or both knee(s) and/or one or both hip(s), as defined by the American College of Rheumatology (ACR) criteria (Altman 1986), who did not suffer from any other arthritic conditions or any other disease that may affect the joints. Participants with all degrees of osteoarthritis, and both primary and/or secondary OA, were eligible. We only included trials with a mixture of participants with different rheumatic diseases if we were able to extract data on the participants with OA.

Types of interventions

Trials including at least one treatment group in which aquatic exercise was applied. We included trials that used all types of exercises (e.g. ROM, strength, aerobics) performed in a therapeutic/heated indoor pool. The use of medication, alternative therapies, or lifestyle changes were described in the included studies, and must have been comparable in both groups studied.

Types of outcome measures

Beneficial outcome measures recommended by OMERACT III (Bellamy 1997) included the following.

Primary outcomes

1. Pain.
2. Disability (e.g. measured by the Activities of Daily Living Scale, Western Ontario and McMaster Universities Arthritis Index (WOMAC), physical function subscale).
3. Quality of life.
4. Radiographs (studies that were over one year in duration) (Bellamy 1997).

Adverse effects

Serious adverse effects from all included trials. .

Search methods for identification of studies

Electronic searches

Bibliographic databases

We searched the following databases up to 28 April 2015: the Cochrane Central Register of Controlled Trials (CENTRAL; the Cochrane Library Issue 1, 2014), MEDLINE (from 1949), EMBASE (from 1980), CINAHL (from 1982), and Web of Science (from 1945) (see Appendix 1).

Furthermore, we checked the following databases: *PEDro* (Physiotherapy Evidence Database): Therapy: Hydrotherapy, Balneotherapy, and the Copenhagen University Library's catalogue in the systematic group covering pool therapy to ensure there were no older studies published as monographs.

Searching other resources

Reference checking

We checked the reference lists of the included trials for further relevant literature.

Other sources

We contacted institutions, societies, and specialists with known expertise in aquatic therapy for further information. In addition, we searched three trials register websites (anzctr.org.au; clinicaltrialsregister.eu; clinicaltrials.gov) for registered trials (on-going or finished).

Data collection and analysis

Selection of studies

Two review authors (EMB and HL) independently screened the abstracts, keywords, and publication type of all articles we obtained from our described literature searches. We resolved any uncertainties or disagreements by discussion. We obtained the full-text articles of all studies that were possibly eligible for inclusion, and assessed them based on the inclusion and exclusion criteria. We listed the excluded trials and their reasons for exclusion in the 'Characteristics of excluded studies' table.

Data extraction and management

Three review authors (EMB, HL, and CBJ) independently extracted data for statistical analysis. We resolved any uncertainties or disagreements by discussion with RC, HD, KBH, and BDS. If more than one measured variable for an outcome domain was present in the study, we chose the outcome measure for analysis in accordance with [Juhl 2012](#).

The list of pain measures (in descending order) were as follows.

1. WOMAC pain sub scale (Likert/100 mm).
2. Pain during activity (visual analogue scale (VAS)).
3. Pain during walking (VAS).
4. Global knee pain (VAS).
5. Pain at rest (VAS).
6. SF-36 (Short Form, bodily pain (BP) sub scale).
7. HAQ (Health Assessment Questionnaire, pain subscale), Lequesne algofunctional index (pain sub scale), AIMS (Arthritis Impact Measurement Scale, pain subscale), Knee-Specific Pain Scale (KSPS), McGill Pain Questionnaire (pain intensity), ASES (Arthritis Self-Efficacy Scale, pain subscale), SES (Schmerzempfindungsskala).
8. Pain at night (VAS), pain during activity (Numeric Rating Scale (NRS)), pain on walking (NRS), number of painful days (days).

The list of disability measures was as follows (in descending order).

1. WOMAC sub scale function (Likert/100 mm).
 2. SF-36 (subscale physical function (PF)).
 3. Physical Composite Score (PCS) based on SF-36, SF-12, or SF-8.
 4. HAQ (Health Assessment Questionnaire disability subscale), PDI (pain disability index), ASES (disability subscale).
- There was no documentation for any order of different measures for quality of life (QoL). However, we used the following list of QoL measures (in descending order).
1. SF-36/SF-12/SF-8.
 2. EuroQoL.
 3. KOOS subscore: QoL.
 4. Quality of well-being.
 5. Arthritis Impact Measurement Scale.
 6. Other scales.

Assessment of risk of bias in included studies

Five review authors (EMB, CBJ, HD, KBH, and HL) independently assessed the risk of bias of the included trials. As recommended by the *Cochrane Handbook for Systematic Reviews of Interventions* ([Higgins 2011](#)), we assessed the following methodological domains.

1. Sequence generation: was the method used to generate the allocation sequence appropriate to produce comparable groups?
2. Allocation concealment: was the method used to conceal the allocation sequence appropriate to prevent the allocation being known in advance of, or during, enrolment?

3. Blinding of participants, personnel, and outcome assessors: were methods used to blind study participants, personnel, and outcome assessors from knowledge of which intervention a participant received?

4. Incomplete outcome data: how complete were the outcome data for the primary outcomes? Were drop-out rates and reasons for withdrawal reported? Were missing data imputed appropriately? We considered an overall completion rate of 80% or higher as a low risk of bias. If completion rates were only provided by group, a less than 80% completion rate in the treatment group was considered a high risk of bias.

5. Selective outcome reporting: were appropriate outcomes reported and were any key outcomes missing?

6. Other potential threats to validity (considering external validity, e.g. relevant use of co-interventions): e.g. what was the funding source of each of the studies?

We explicitly judged each of these criteria as either: adequate = low risk of bias; inadequate = high risk of bias; or unclear = either lack of information or uncertainty over the potential for bias.

We allocated trials to one of the following groups.

1. Low risk of bias (five or six criteria met).
2. Unclear risk of bias (three to four criteria met).
3. High risk of bias (less than three criteria met).

We documented other methodological issues, such as baseline comparability, and sample size, in the 'Characteristics of included studies' table.

Analyses and presentation

We performed an overall analysis for both knee and hip OA. In addition, we analysed the results in two subgroups.

1. A group suffering from knee OA alone.
2. A group suffering from hip OA alone.

We analysed the included trials in the following domains: pain, disability, and quality of life.

Furthermore we performed the analyses at two time points: immediately after the intervention and at follow-up. We performed an analysis of the relative risk (RR) due to withdrawal from the aquatic exercise group compared to the control group. Finally, we estimated the NNTH (Number Needed to Treat for an additional harmful outcome) from the RR, where the assumed control risk was the number of withdrawals in the control group.

Comparisons

We only pooled data if there were at least two trials of comparable aquatic-therapy protocols, with the same conditions and comparable outcome measurements. We used 'after' data both immediately after the treatment period, and at follow-up. We performed statistical analyses using Review Manager (RevMan) software (RevMan 2014).

Continuous outcomes

Since trials used similar, but not identical, instruments to measure pain, disability, and quality of life, we calculated the standardized mean difference (SMD) values. When analysing quality of life measurements we used a weighted average of subscores, and estimated the standard deviation (SD) as the square root of the weighted mean of the variance. A negative value indicates benefit of the intervention. We assessed heterogeneity by applying a Chi² test, and the I² test. If the Chi² test gave a statistical significant result or the I² statistic test showed a value greater than 50%, or both, we considered this to indicate substantial heterogeneity. We used a random-effects model in all analyses. In order to change the SMD into metrics we applied the Bliddal 2009 approach and then transformed the SMD and 95% CI into a VAS ranging from 0 to 100.

Summary of findings table.

We created a 'Summary of findings' table by using the following outcomes: immediate post-treatment pain, disability, quality of life, withdrawals due to adverse events, and radiographic evaluation. We used the five GRADE (Grades of Recommendation, Assessment, Development and Evaluation) considerations (study limitations, consistency of effect, imprecision, indirectness and publication bias) to assess the quality of a body of evidence for stated outcomes (Schünemann 2011a; Schünemann 2011b).

Outcomes pooled using SMDs were re-expressed as absolute mean differences (or changes) by multiplying by a representative control group baseline SD based on Bliddal 2009 (Bliddal 2009).

In the Comments column of the 'Summary of findings' table, we have presented the absolute change, the relative percent change from baseline and the number needed to treat. We estimated the NNTB (Number Needed to Treat for an additional beneficial outcome) from the odds ratio (OR). We transformed the SMD value to the OR using the equation of Chinn 2000. We set the patient expected event rate (PEER) to 0.4 for pain and to 0.26 for disability, based on Tubach 2005.

RESULTS

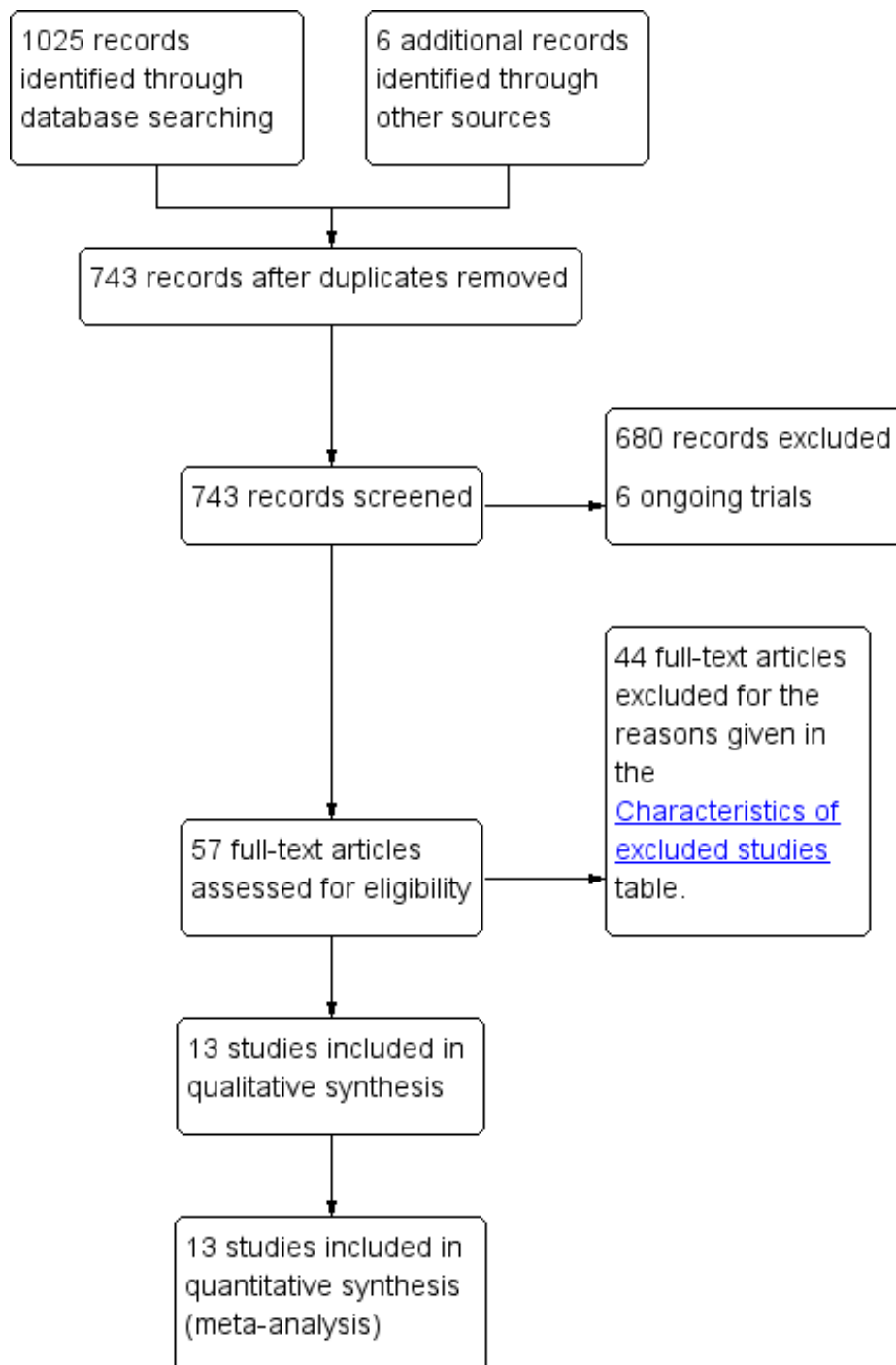
Description of studies

Results of the search

743 articles were identified. Of these 680 was excluded based upon title and abstract, 44 were excluded based upon full text reading (See Characteristics of excluded studies), and 6 were identified through search for ongoing trials (registered in anzctr.org.au; clinicaltrialsregister.eu; clinicaltrials.gov). Two of these were already included (Arnold 2008; Patrick 2001) and four identified as possible

studies to be included later (Faulkner 2006; Sct. George Hospital; Taglietti 2014; Yazigi 2013). Thus we included 13 studies(Figure 1).

Figure 1. Study flow diagram.



Included studies

The 13 included RCTs with a total of 1190 participants met the inclusion criteria (Arnold 2008 (N = 51); Cochrane 2005 (N = 312); Foley 2003 (N = 70); Fransen 2007 (N = 96); Hale 2012 (N = 39); Hinman 2007 (N = 71); Kim 2012 (N = 70); Lim 2010 (N = 50); Lund 2008 (N = 54); Patrick 2001 (N = 249); Stener-Victorin 2004 (N = 30); Wang 2006 (N = 42); Wang 2011 (N = 56). See the 'Characteristics of included studies' table for further information.

Most participants were female (75%), with an average age of 68 years, with a range of 62 to 74 years. The average body mass index (BMI) was 29.4, and the range was 26.6 to 33. The mean duration of hip or knee osteoarthritis (OA) was 6.7 years, but with a great variation of the included participants; for example, in one study it lasted from four months to 15 years (Stener-Victorin 2004). The mean aquatic exercise duration was 12 weeks, with a range of six to 20 weeks. The mean adherence rate was 87% (standard deviation (SD) 5.4%). Eight included trials recruited participants with knee or hip OA, or both (Cochrane 2005; Foley 2003; Fransen 2007; Hale 2012; Hinman 2007; Kim 2012; Patrick 2001; Wang 2006). Three trials recruited participants with knee OA only (Lim 2010; Lund 2008; Wang 2011). Two trials recruited participants with hip OA alone (Arnold 2008; Stener-Victorin 2004).

In one trial, Foley 2003, the trial authors did not present any mean and SD values, but instead presented a median and an interquartile range (IQR). We used the median value as a substitute for the mean, and recalculated the IQR to a SD by assuming normal distribution and by calculating SDs from the IQR.

In another trial, Lund 2008, the trial authors gave no SD value at follow-up, but only at baseline. Therefore we based the SD at follow-up on a calculation of the SD from the standard error (SE) value.

Excluded studies

We excluded 44 studies (see the 'Characteristics of excluded studies' table for further information): two studies due to the insufficient presentation of outcome data, i.e. the precise estimates of the effect of the aquatic exercise was not given (Ahern 1995; Sylvester 1990), and 42 studies as they did not fulfil the inclusion criteria of this Cochrane review. Thus, it is unlikely that by including these two studies the results would have changed significantly. Also we excluded two studies included in a previous version of this Cochrane review (Bartels 2007): one because the same trial data was used in a later published version of a thesis (Wang 2004), and one as it did not include a control group (Wyatt 2001).

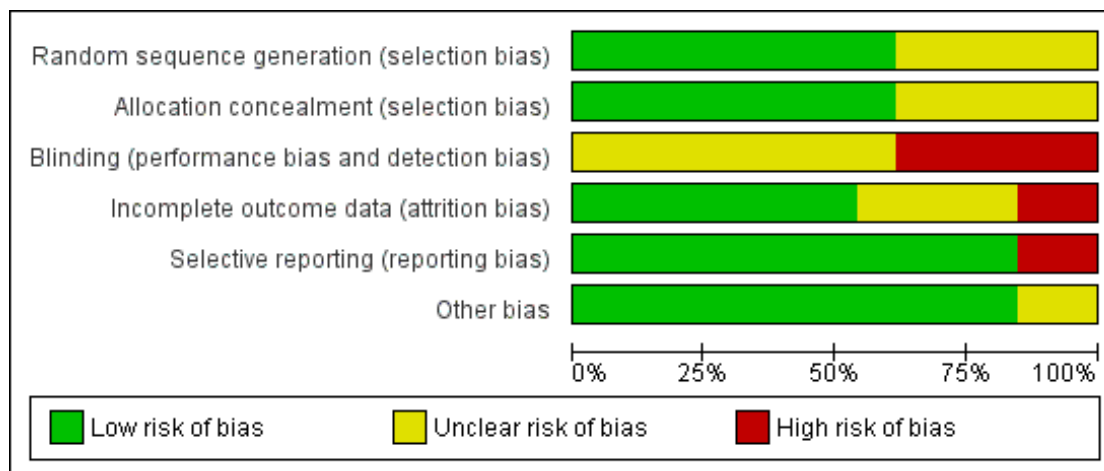
Risk of bias in included studies

Using the 'Risk of bias' assessment described above, only one included trial was at low risk of bias (A) (Hinman 2007). Nine included trials were at unclear risk of bias (B) (Arnold 2008; Cochrane 2005; Foley 2003; Fransen 2007; Hale 2012; Lim 2010; Lund 2008; Patrick 2001; Wang 2011), and three trials were at high risk of bias (C) (Kim 2012; Stener-Victorin 2004; Wang 2006). In conclusion, the evidence presented in this review is based upon high risk of bias of the included studies ('Characteristics of included studies' table; Figure 2, Figure 3).

Figure 2. 'Risk of bias' summary: review authors' judgements about each 'Risk of bias' item for each included trial.

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding (performance bias and detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Arnold 2008	+	+	-	-	-	+
Cochrane 2005	+	+	?	+	+	+
Foley 2003	+	+	?	+	+	?
Fransen 2007	+	+	?	+	+	?
Hale 2012	+	+	?	?	+	+
Hinman 2007	+	+	?	+	+	+
Kim 2012	+	?	-	?	-	+
Lim 2010	?	?	?	+	+	+
Lund 2008	?	+	?	+	+	+
Patrick 2001	?	?	-	+	+	+
Stener-Victorin 2004	?	?	-	-	+	+
Wang 2006	?	?	-	?	+	+
Wang 2011	+	+	?	?	+	+

Figure 3. 'Risk of bias' graph: review authors' judgements about each 'Risk of bias' item presented as percentages across all included trials.



Effects of interventions

See: [Summary of findings for the main comparison](#)
See 'Summary of findings' table 1.

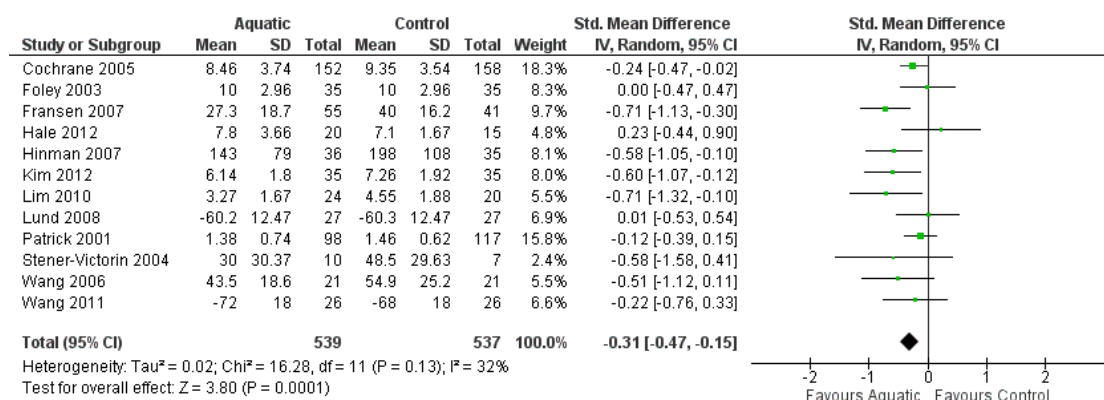
Effect on pain, disability, and quality of life immediately after aquatic exercise

All included trials

Effect of aquatic exercise on pain compared to control

Our analysis of all trials that self-reported pain (12 trials, excluding [Arnold 2008](#)) showed a statistically significant pain reduction (SMD -0.31 , 95% confidence interval (CI) -0.47 to -0.15 ; Analysis 1.1), and no sign of heterogeneity ([Figure 4](#)). This effect corresponded to five points lower (95% CI three to eight) on a 0 to 100 scale compared to the control group. However, the one extreme of the 95% CI showed a clinical non-relevant difference of effect.

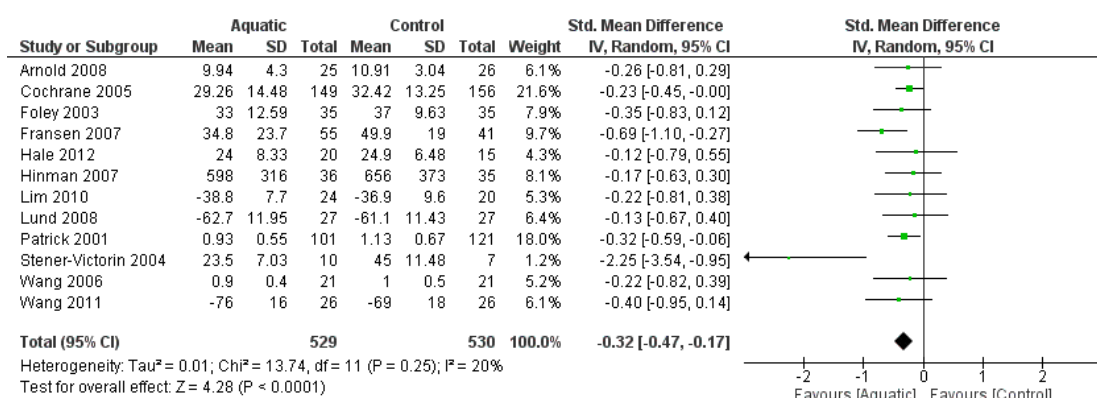
Figure 4. Forest plot of comparison: I Aquatic exercise vs control immediately after treatment - knee & hip OA, outcome: I.I Pain.



Effect of aquatic exercise on disability compared to control

Analysis of all trials that measured self-reported disability (12 trials, excluding Kim 2012) showed a statistically significant reduction in disability (SMD -0.32 , 95% CI -0.47 to -0.17 ; Analysis 1.2), and negligible heterogeneity (Figure 5). This effect corresponded to five points lower (95% CI three to eight) on a 0 to 100 scale compared to the control group. However, the one extreme of the 95% CI showed a clinical non-relevant difference of effect.

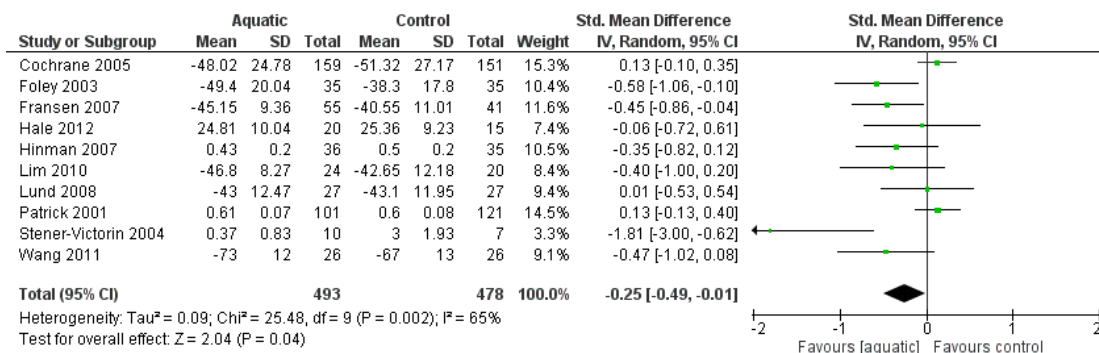
Figure 5. Forest plot of comparison: I Aquatic exercise vs control immediately after treatment - knee & hip OA, outcome: I.2 Disability.



Effect of aquatic exercise on quality of life (QoL) compared to control

Our analysis of all trials that measured QoL (10 trials, excluding Arnold 2008, Kim 2012, and Wang 2006) showed a statistically significant improvement in QoL (SMD -0.25 , 95% CI -0.49 to -0.01 ; Analysis 1.3). This effect corresponded to seven points higher (95% CI 0 to 13 points higher) on a 0 to 100 scale compared to the control group. However, we observed high heterogeneity (I² statistic = 65%; Figure 6), and the right extreme of the 95% CI showed a clinical non-relevant difference of effect.

Figure 6. Forest plot of comparison: I Aquatic exercise vs control immediately after treatment: knee & hip OA, outcome: I.3 QoL.



Knee alone

The three included trials that only recruited participants with knee OA showed no statistically significant effect neither after exercise or at follow-up. We did not observe any heterogeneity in our analyses of pain (Analysis 2.1), disability (Analysis 2.2), and QoL (Analysis 2.3).

Hip alone

One trial, [Stener-Victorin 2004](#), evaluated the effect of aquatic exercise on pain and QoL for participants with hip OA alone, but showed no statistically significant effect either after exercise or at follow-up (Analysis 3.1; Analysis 3.3). Two included trials, [Arnold 2008](#) and [Stener-Victorin 2004](#), examined the effect on self-reported disability, but there was no statistically significant result (SMD -1.16, 95% CI -3.11 to 0.78; Analysis 3.2), and a high degree of heterogeneity.

Effect on pain, disability, and QoL at follow-up after aquatic exercise

Three included trials performed measurements some weeks after the end of the aquatic exercise intervention. One trial measured 24 weeks after the exercise period ([Cochrane 2005](#)), one trial measured 12 weeks after the exercise period ([Lund 2008](#)), and one trial measured four, 12, and 24 weeks following the exercise period ([Stener-Victorin 2004](#)). We did not observe any statistically significant effect on pain (SMD -0.30, 95% CI -0.92 to 0.32; Analysis 4.1), disability (SMD -0.32, 95% CI -0.83 to 0.20; Analysis 4.2), or QoL (SMD -0.15, 95% CI -0.64 to 0.34; Analysis 4.3). In all cases we observed high heterogeneity.

For one trial, [Lund 2008](#), that included participants with knee OA alone, we did not observe any effect on either pain (SMD 0.14, 95% CI -0.39 to 0.68; Analysis 5.1), disability (SMD -0.13,

95% CI -0.67 to 0.40; Analysis 5.2), or QoL (SMD -0.11, 95% CI -0.65 to 0.42; Analysis 5.3). One trial, [Stener-Victorin 2004](#), included participants with hip OA and we observed a statistically significant effect at follow-up on pain (SMD -1.66, 95% CI -2.82 to -0.51; Analysis 6.1), disability (SMD -1.47, 95% CI -2.58 to -0.35; Analysis 6.2), and QoL (SMD -1.09, 95% CI -2.15 to -0.04; Analysis 6.3). However the right extreme of the 95% CI for QoL showed a clinical non-relevant difference of effect.

Radiographic evaluation

No included trials performed any type of radiographic evaluation. However, since all but one trial were less than one year in duration, this outcome was irrelevant ([Bellamy 1997](#)).

Adverse events

Two trials reported no increase in self-reported pain or other symptoms ([Foley 2003](#); [Wang 2006](#)). [Foley 2003](#) also reported that there was no difference in drug consumption between the groups. One trial reported minor adverse effects which were temporary, such as mild joint discomfort, lumbar pain, and cramps in the calf or foot, but none that prevented further participation in the trial ([Hinman 2007](#)). One trial, [Fransen 2007](#), reported one withdrawal from the aquatic group due to low-back pain. Two trials concluded that none of the people lost to follow-up were due to the exercise interventions ([Cochrane 2005](#); [Hinman 2007](#)). Two trials reported an accident on the pool deck as the only adverse event ([Arnold 2008](#); [Kim 2012](#)). Two trials had an exercise trainer or assistant to monitor adherence and adverse effects ([Lim 2010](#); [Wang 2011](#)). In one aquatic exercise group one participant dropped out due to a heart problem ([Lim 2010](#)), and another participant reported dizziness during exercise ([Wang 2011](#)). In one trial, [Hale](#)

2012, two participants reported that the water-based exercises aggravated the pain in their legs and stopped attending during week 3 of the programme. The remaining two trials, [Patrick 2001](#) and [Stener-Victorin 2004](#), did not report on adverse effects at all. Thus, 11 of the 13 included trials reported adverse events, and in all trials but one ([Lim 2010](#)) the adverse events should be characterized as minor. A meta-analysis of people lost to follow-up from both the aquatic exercise group and the control group showed a relative risk (RR) for withdrawal in the aquatic exercise group compared to control group 1.21 (95% CI 0.94 to 1.56).

DISCUSSION

Summary of main results

Overall this Cochrane review update shows that aquatic exercise has a small, short-term clinically-relevant effect on patient-reported pain, disability, and quality of life (QoL) in people with knee and hip osteoarthritis (OA) after completion of an aquatic exercise programme. However, it is unclear whether this effect is sustained based on the current evidence. The overall analyses of the immediate effect of aquatic exercise shows a precise and consistent result, despite a heterogeneous participant group with mixed knee and hip OA. Compared to the control group, the participants who did aquatic exercise showed a five point lower mean pain and mean disability on a 0 to 100 scale, and for QoL a seven point higher mean QoL on a 0 to 100 scale, based on moderate quality evidence ([Summary of findings for the main comparison](#)).

Overall completeness and applicability of evidence

In order to achieve the effects found in this Cochrane review, the intervention should be aquatic exercise and not passive aquatic treatment only, such as spa- or balneotherapy where the main focus is on the effect of temperature and minerals, but not of an active intervention. Finally, relevant outcomes must be measured, i.e. patient-relevant outcomes as pointed out by OMERACT ([Bellamy 1997](#)). The 13 trials clearly included participants with knee and hip OA, offered a physical exercise intervention in water, and measured the effect on pain and disability - the main outcome measures as pointed out by OMERACT ([Bellamy 1997](#)). On the other hand, when we analysed the effect on participants with knee or hip OA alone, we were only able to include a few trials in our meta-analyses. Thus the evidence on knee and hip OA alone is poor, and further studies focusing on knee or hip OA alone are needed.

The primary results of this Cochrane review are based upon meta-analyses that combined trials including participants with knee or

hip OA. However, the knee and hip joints are very different both in type and loading. An exercise programme that shows an effect in people with knee OA may not be efficacious in people with hip OA, and vice versa. Therefore exercise programmes applied to a group of people with mixed knee and hip OA may not be as efficacious as the exercise programmes applied to a group of people with either knee or hip OA, given the possibility of specifically focusing the exercise programme towards the group of people. Only two trials included participants with hip OA alone ([Arnold 2008](#); [Stener-Victorin 2004](#)), and only three trials included participants with knee OA alone ([Lim 2010](#); [Lund 2008](#); [Wang 2011](#)). Eight trials included a mixed group of participants with knee and hip OA ([Cochrane 2005](#); [Foley 2003](#); [Fransen 2007](#); [Hale 2012](#); [Hinman 2007](#); [Kim 2012](#); [Patrick 2001](#); [Wang 2006](#)). Therefore, we were unable to make a specific conclusion for each joint alone, but only a conclusion for a mixed group of participants with knee and hip OA.

Recently published meta-analyses support the importance of focusing on one type of exercise with a particular treatment aim ([Escalante 2010](#); [Jansen 2011](#); [Juhl 2013](#)) where single-type exercise programmes were more efficacious than programmes that included different exercise types. Resistance exercise can increase the myofibrillar protein response, and aerobic exercise can increase mitochondrial proteins in the muscle ([Hawley 2009](#)).

Apart from the effect of aquatic exercise on pain, disability, and QoL in participants with OA found in our Cochrane review, other studies of aquatic exercise have shown that relevant outcomes can improve following treatment. These include improvement in functional tests, such as “sit-and-reach” ([Colado 2009](#)), “knee-push-up” ([Colado 2009](#)), “timed-up-and-go” ([Tsourlou 2006](#)), knee extensor strength ([Meredith-Jones 2011](#); [Sato 2009](#)), and 60 second squats ([Colado 2009](#)). Overall, it seems possible to achieve the same degree of improvement in both aerobic capacity and muscle strength with aquatic exercise as with land-based exercise ([Avelar 2010](#); [Avellini 1983](#); [Bocalini 2008](#); [Colado 2009](#); [Meredith-Jones 2011](#); [Nikolai 2009](#)), and these improvements are independent of gender and age ([Meredith-Jones 2011](#)).

As this Cochrane review shows, aquatic exercise only seems to show minor adverse effects which are unimportant for adherence to treatment. One included trial reported that 11 participants in the land-based exercise group reported adverse effects of the exercise, and three of these stopped due to this ([Lund 2008](#)). In the aquatic group only three participants reported adverse effects, and all continued their exercise programme. Furthermore, another study of land-based exercise for participants with knee OA indicates an increase in knee oedema following exercise ([Røgind 1998](#)). Report of adverse events following treatment is important for any treatment, since adverse events, even minor ones, may decrease exercise adherence in a group of participants who may naturally avoid exercise due to fear of increased pain. In future studies of effect of exercise in people with OA, study authors should report adverse effects in accordance with the Ioannidis and Lau classifica-

tion (Ioannidis 2001) to give a complete picture of effects of this type of treatment.

Knee or hip OA is common and, when assessed by x-ray, appears to affect older people in particular (Altman 1986). However, knee traumas (e.g. meniscal tears, anterior cruciate ligament damage) are related to knee OA at an earlier age (Roos 2009). Currently, there is no cure, and the main focus of prevention and treatment is to diminish the symptoms, i.e. pain and disability. The economic consequences of OA, if it develops into disability, are serious (Bitton 2009). Exercise may delay development of disability caused by OA and this Cochrane review supports earlier findings that show exercise therapy can diminish pain and disability in people with knee OA (Fransen 2008).

Quality of the evidence

We downgraded the quality of evidence of the included trials due to high risk of bias ('Characteristics of included studies' table). We only considered one of the 13 included trials as at low risk of bias, and three trials at high risk of bias. However, eight included trials were unclear regarding blinding as it was not possible to blind either the therapist or the participant to the intervention, but in all those trials the outcome assessor was blinded. Even though the awareness of being treated may provide a positive bias towards treatment when compared to a control group not exposed to treatment (Sherman 2008), the high number of trials in which the outcome assessor was blinded reduced the risk of bias. Considering the high risk of bias, and the wide confidence intervals (CIs), our conclusions cannot be final. Thus we have tried to be very specific when making suggestions for further studies. Other reasons for the lack of an unambiguous conclusion could be the combination of hip and knee OA, the very different kinds of exercise, and the different ways to evaluate pain, disability, and quality of life. Initiatives, such as OMERACT (Bellamy 1997), to identify the relevant and useful outcome measures are needed. On the other hand, the quality of the evidence regarding pain, disability, and quality of life was of moderate quality ('Summary of findings' table 1) using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach.

Potential biases in the review process

When performing a systematic review the most important part is the literature search as the rest of the procedure rests on the available publications. We expected a low risk of bias in that respect, as we searched several databases, checked the reference lists of all included trials and other reviews identified, and asked institutions, societies, and specialists known to have expertise in aquatic therapy for further information. In addition, we searched three trials register websites (anzctr.org.au; clinicaltrialsregister.eu; clinicaltrials.gov) and identified two trials we had already included (Arnold

2008; Patrick 2001), and four relevant trials to be included when completed and published (Faulkner 2006; Sect. George Hospital; Taglietti 2014; Yazigi 2013).

Two review authors independently screened abstracts and full-text articles, and we resolved any differences by discussion. The high number of studies that we evaluated as full-text articles may indicate that we identified most available studies dealing with aquatic exercise for people with knee and hip OA. However, several studies mixed aquatic exercise and balneotherapy and/or mixed participants with rheumatoid arthritis, spondyloarthropathy, and/or OA in knee, hip, and/or other joints. Thus the clarity of the conclusion could have been higher if it was possible to distinguish between participants with knee and hip OA and other diseases, and between exercise and spa- or balneotherapy (typically passive treatment).

We have also minimized the risk of bias regarding 'Risk of bias' assessments and meta-analyses. Five review authors independently performed the 'Risk of bias' assessments, and we achieved consensus by discussion. Two review authors independently performed data extraction and analyses, and resolved any differences by discussion.

Agreements and disagreements with other studies or reviews

Since the first published version of this Cochrane review (Bartels 2007), two systematic reviews has been published: one focused solely on people with knee OA and aquatic exercise (Lu 2015) and one focused on people with lower limb OA and aquatic exercise (Waller 2014). Both reviews included trials that we also included in this Cochrane review. The meta-analyses from both reviews support the effect on pain, function, and quality of life as found in this Cochrane review.

Many clinicians and patients have noted that there are specific benefits to using aquatic exercise, and that these benefits are substantial enough to outweigh the inconvenience of performing exercises in a swimming pool instead of on land (Becker 2009; Bocalini 2010; Campbell 2003; D'Acquisto 2001; Hall 2008; Meredith-Jones 2011). Several study authors have also argued that aquatic exercise is fundamentally different from exercise on land, and that the two exercise methods should not be compared directly (Hall 2008; Meredith-Jones 2011). A number of reasons have been given for this argument. The hydrostatic pressure during immersion increases the preload volume of blood in the right ventricular, leading to a higher stroke volume (from 70 mL/min to 100 mL/min), and with this a lower heart rate (Becker 2009). In addition, the VO₂ consumption is three times higher in people who do aquatic-based exercise compared to people who do land-based exercise at the same intensity (Becker 2009). Compared to land-based exercise, the same effect on aerobic capacity may therefore be achieved with aquatic exercise with less exertion (Becker 2009). Surprisingly, the amount of blood circulated to the muscles during exercise in water

is increased compared to land-based exercise (from 1.8 mL/min/100 g tissue to 4.1 mL/min/100 g tissue) (Becker 2009), indicating that exercise in water could be more effective compared to land-based exercise. For people with painful joints and a low physical activity level (Farr 2008), an environment stimulating to higher exercise efficiency with less exertion seems a promising starting point when wishing to increase physical activity and exercise level. However, the increased preload of the heart may be dangerous for people with a heart condition. This effect is present as soon as the person is immersed in water, even before the exercise starts, and will further increase the demands on the heart (Asahina 2010).

Swimming pools for aquatic exercise are typically heated to 32°C to 36°C (89°F to 97°F) to avoid people getting cold, and warm water may diminish pain. The pain-relieving effect is suggested to be due to the joint effect of warm water and buoyancy on thermo- and mechanoreceptors (Hall 2008), or on the effect of warm water to increase blood flow and thereby reduce signal molecules responsible for activation of nociceptors (Hall 2008). Another effect of water immersion is due to the hydrostatic pressure, which leads to smaller peripheral oedema and possibly a decreased sympathetic activity, leading to pain reduction (Hall 2008). Just by considering the pain reduction part, it is unsurprising that people with chronic pain in one or more joints will be more motivated to perform, and therefore benefit from, aquatic exercise (Hall 2008).

Exercise while immersed in water is fundamentally different from land-based exercise due to the buoyancy, resistance to movements in all directions (due to the viscosity of the water), the turbulence created by the person's movements, and the hydrostatic pressure present. The unique environment leads to less load on weight-bearing joints, a positive disposition towards the exercise because it is easier to move, activation of more muscles due to the resistance in all directions, and a greater range of movement due to buoyancy (Meredith-Jones 2011; Sato 2009). An important aspect is that the water environment creates fewer adverse events during exercise (Lund 2008; Takeshima 2002), it reduces a person's fear of falling during exercise, and overweight people have reported that they like to exercise without showing the whole body during exercise (Takeshima 2002). Considering that a high proportion of people with OA typically are overweight, all aforementioned aspects could lead to higher exercise adherence.

Conversely, although buoyancy is a strong argument for choosing aquatic exercise treatment due to the unloading of joints, exercises involving loading seem to be beneficial for people with knee OA (Fransen 2008). Furthermore, land-based exercise seems to improve the quality of knee cartilage (Roos 2005). However, malalignment or lack of neuromuscular control may lead to focal overload of the cartilage during land-based exercise. For example, varus-malalignment, either functional or biomechanical, or both, leads to a higher load on the medial part of the knee cartilage (Chang 2004). Improvement of a person's neuromuscular control may diminish the malalignment and lead to a more even distribution of the load on the cartilage. In such cases aquatic exercise is,

due to presence of turbulence in the water and better possibilities for advanced neuromuscular training, a promising modality. The choice of exercise type must therefore be decided based on the individual person's condition.

As for other exercise programmes, the lack of a long-term effect is also seen for aquatic exercise (Bocalini 2010). In light of this, the goal for aquatic exercise should firstly be to help inactive people with knee or hip OA to increase their daily physical activity, and maybe even start maintenance of physical training. Furthermore, the aquatic exercise could be performed with the aim of improving the person's neuromuscular control in their lower extremities, and thereby diminish the deteriorating consequences of OA. However, one should bear in mind that very few trials measured the long-term effect, thus the identified lack of effect could be due to the paucity of trials, and not the lack of effect. Considering the above-mentioned considerations and benefits of aquatic exercise, aquatic exercise may be a relevant option for people with knee and hip OA. An important consideration when designing an exercise programme is to define the objectives behind the choice of exercises in the programme for each participant or group. Aquatic exercise may therefore be considered as the first part of an exercise therapy programme to introduce disabled people or people with poor adherence to land-exercise to training. Further physical therapy interventions may then continue on land, but the balance between the two types is still unclear based on the available evidence.

AUTHORS' CONCLUSIONS

Implications for practice

Based upon moderate quality evidence, aquatic exercise has beneficial effects on people with knee or hip OA, or both, i.e. a small but clinically relevant decrease in pain and disability, and small but clinically relevant increase in quality of life. The number of RCTs in this research area is still too few to give further recommendations on how to use aquatic exercise to treat people with knee or hip OA, or both. There is a small short-term effect on for people with either knee and/or hip OA at the end of an aquatic training programme. We did not find any statistically significant difference when we analysed this effect for people with hip OA or knee OA alone, which may be due to the low number of studies on aquatic exercise. The long-term effect is unclear due to the paucity of studies.

Implications for research

Further research is needed in order to optimize the use of aquatic exercise to treat the symptoms of people with well-established knee and hip OA (according to the American College of Rheumatology (ACR) criteria, or other well-established criteria). Participants should at least be characterized by age, sex, body mass index (BMI),

and duration of disease, and classified as having either mild, moderate, or severe OA in order to establish evidence for which participants benefit from which exercise programme. These studies must be properly designed RCTs comparing aquatic exercise with control treatment, pharmacological treatment or land-based exercise. The main outcomes must be at least pain, disability, quality of life, and fatigue, as recommended by OMERACT (Bellamy 1997), and the effect should be measured immediately after intervention and after a sufficient follow-up time. These outcome measures should be supplemented by measuring structural change in order to monitor the mechanism behind the effect of aquatic exercise.

Furthermore, the interventions need to be sufficiently described according to type of exercise and dose (intensity, frequency, and duration) to establish the optimal intervention.

ACKNOWLEDGEMENTS

We thank the staff at Interlibrary Loan Department, Copenhagen University Library North, for finding even the most obscure references.

The Oak Foundation supported this Cochrane review.

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- * Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

Characteristics of included studies [ordered by study ID]

Arnold 2008

Methods	<p>Randomization: computer generated sequence. Allocation: concealed. The primary outcome was assessor blinded; there was no blinding of secondary outcomes Losses to follow-up: approximately 30%. The trial authors did not perform a sufficient intention-to-treat (ITT) analysis</p>
Participants	<p>Participants were recruited by newspaper advertisement and posters displayed in clinics, recreational facilities, senior residences, and physician offices Hip OA criteria.</p> <ol style="list-style-type: none"> 1. Older than 65 years. 2. Presence of hip pain for 6 months or longer. 3. Diagnosed with hip osteoarthritis (OA) X-ray or medical confirmation of OA. <p>83 participants were randomized to either aquatic exercise and education (N = 28), aquatic exercise (N = 27), or a control group (N = 27) 71% female participants. Mean age (SD): 71.1 years (6.9). Mean BMI (SD): 30.2 (5.1). OA severity: not mentioned.</p>
Interventions	<p>The aquatic exercise group met twice per week for 11 weeks at a community recreational facility (the water temperature kept at approximately 30°C) Sessions lasted 45 minutes with participants exercising in chest water depth. The control group did not receive any intervention.</p>
Outcomes	<p>Outcomes were measured after intervention at 11 weeks. Pain: not measured. Disability: arthritis impact measurement scale version 2 (AIMS-2) (0 to 25) Quality of life (QoL): not measured.</p>
Notes	<p>No commercial funding. This trial was funded by the Canadian Institute of Health Research Regional Partnership Program and the Physiotherapy Foundation of Canada</p>

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	A - Adequate. Participants were randomly assigned by an individual not involved in the research project using a computer generated programme to randomize numbers 1 to 3 for each stratified set (Urbaniak GC, Plous S. The Research Randomizer; www.randomizer.org)

Arnold 2008 (Continued)

Allocation concealment (selection bias)	Low risk	A - Adequate. Participants were blinded to group assignment until after baseline testing, when given a sealed opaque envelope revealing their group assignment.
Blinding (performance bias and detection bias) All outcomes	High risk	C - Inadequate. Blinded outcome assessor. Participant-reported disability was assessed using a questionnaire The primary investigator assisted with the questionnaire administration and was not blinded to group assignment
Incomplete outcome data (attrition bias) All outcomes	High risk	C - Inadequate. There was approximately 30% dropout (18 out of 54) and no ITT analysis
Selective reporting (reporting bias)	High risk	C - Inadequate. No outcomes on pain were reported.
Other bias	Low risk	A - Adequate.

Cochrane 2005

Methods	Randomization: computer generated random sequence. Allocation: concealed. Assessor: blinded. Losses to follow-up: 25% to 27%. The trial authors performed an ITT analysis.
Participants	The trial authors recruited participants from a combination of general practitioner (GP) registers and an advertisement in the local press. Participants had hip or knee OA, or both OA criteria. 1. Older than 60 years. 2. Current symptoms of pain and stiffness. 3. X-ray or medical confirmation of OA. 312 participants were randomized to aquatic exercise intervention (N = 153) or control (N = 159) 63% were female. Mean age (SD): 69.5 years (6.0). BMI = 50% of participants were over 30 in BMI. OA severity: not mentioned.

Interventions	Aquatic exercise: stretching, strengthening, and aerobic exercises, primarily of low to moderate intensity. Sessions of 1 hour, twice per week, 3 months supervised, 9 months unsupervised, for a total of 84 sessions Control: structured telephone interview quarterly monitoring changes in exercise behaviour and other treatment
Outcomes	Measured after intervention at 12 months and follow-up (18 months) Pain: Western Ontario and McMaster Universities Arthritis Index (WOMAC) (0 to 20) Disability: WOMAC (0 to 68). QoL: SF-36 (0 to 100).
Notes	There was no commercial funding. The National Coordinating Centre for Health Technology Assessment acting on behalf of the NHS Executive (Project No. 96/32/99) funded this trial

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	A - Adequate. Randomization was performed from a computer generated random sequence
Allocation concealment (selection bias)	Low risk	A - Adequate. Participants were allocated to a group according to this sequence only after they had been to baseline testing and had agreed to participate in the trial, regardless of group allocation
Blinding (performance bias and detection bias) All outcomes	Unclear risk	B - Unclear. Blinded outcome assessor. Participant reported pain and disability was assessed using a questionnaire All questionnaires were marked only with a patient code and were processed by a research administrator without knowledge of group allocation. Coding was only revealed after all data had been entered, checked, and validated, and before interim (for monitoring and reporting purposes) and final analysis
Incomplete outcome data (attrition bias) All outcomes	Low risk	A - Adequate. Forty-two subjects (27%) dropped out from the exercise group and 39 (25%) from the control group in this period, but the trial authors performed primary analysis on an ITT basis, with last available measure-

		ment carried forward
Selective reporting (reporting bias)	Low risk	A - Adequate. Key outcomes participant reported pain and disability were reported
Other bias	Low risk	A - Adequate.

Foley 2003

Methods	Randomization: computer generated random sequence. Allocation: concealed. Assessor: blinded. Losses to follow-up: 20% (aquatic) and 26% (land-based). The trial authors performed an ITT analysis.
Participants	Participants were recruited from physiotherapy, orthopedic, and rheumatology departments at the hospital, the orthopedic department of another hospital, and by local advertisement in the community. Participants had hip or knee OA, or both OA criteria (both knee and hip): 1. Over 50 years old. 2. Radiological diagnosis of hip or knee OA. 105 participants were randomized to either aquatic exercise (N = 35), land-based exercise (N = 35), or a control (N = 35) group 49.5% were female. Mean age (SD): 70.9 years (8.8). BMI: not mentioned. OA severity: not mentioned.
Interventions	Aquatic exercise: stretching and strengthening exercise. 30 mins each session, 3 times per week for 6 weeks Land-based: strengthening exercise. 30 mins each session, 3 times per week for 6 weeks Control: 3 telephone calls to record any changes in condition and treatment
Outcomes	Measured after intervention at 6 weeks. Pain: WOMAC (0 to 20). Disability: WOMAC (0 to 68). QoL: SF-12 (0 to 86).
Notes	Funding was not reported.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	A - Adequate. A person external to the study created a computer-generated randomization list

Foley 2003 (Continued)

		and it was managed by an external department
Allocation concealment (selection bias)	Low risk	A - Adequate. After baseline assessment, a person from the pharmacy department assigned participants to treatment group according to sequentially numbered, sealed, opaque envelopes
Blinding (performance bias and detection bias) All outcomes	Unclear risk	B - Unclear. Blinded outcome assessor. Participants reported disability using questionnaire. A single trained investigator collected all outcome measures at baseline before randomization, and a single "blinded" outcome assessor at 6 weeks
Incomplete outcome data (attrition bias) All outcomes	Low risk	A - Adequate. Seven participants (20%) dropped out from the hydrotherapy group and 3 (9%) from the control group. The trial authors used an ITT approach in all analyses, and used the last observation carried forward to impute data missing at follow-up
Selective reporting (reporting bias)	Low risk	A - Adequate. Trial authors reported key outcomes of participant reported pain and disability
Other bias	Unclear risk	B - Unclear. It was unclear whether the participants received any co-intervention or not

Fransen 2007

Methods	Randomization: by computerized randomization schedule in blocks of 30 Allocation: concealed. Assessor: blinded. Losses to follow-up: 12% The trial authors performed an ITT analysis.
Participants	Participants were recruited via advertisement in local newspapers, through presentations at local social clubs for older people, and through referral from local general practitioners and rheumatologists. Participants had hip or knee OA, or both OA criteria (both knee and hip). 1. Between 59 to 85 years old. 2. ACR criteria. 3. Current and chronic hip or knee pain > 1 year.

	<p>152 participants randomized to either aquatic exercise (N = 55), Tai Chi exercise (N = 56), or control (N = 41)</p> <p>Aquatic exercise: 73% female; control: 83% female.</p> <p>Mean age (SD): aquatic exercise: 70 years (6.3); control: 69.6 (6.1)</p> <p>BMI: aquatic exercise: 30.0 (5.0); control: 30.7 (5.0).</p> <p>OA severity: not mentioned.</p>
Interventions	<p>Aquatic exercise (hydrotherapy): 1 hour, twice per week for 12 weeks. Combination of aerobic and strengthening exercises</p> <p>Tai Chi: 1 hour, twice per week for 12 weeks. (excluded from the meta-analyses of this Cochrane review)</p> <p>Control: waiting list (following the first 12 weeks, randomized to either Tai Chi or aquatic exercise)</p>
Outcomes	<p>Measured after intervention at 12 weeks.</p> <p>Pain: WOMAC (0 to 100).</p> <p>Disability: WOMAC (0 to 100).</p> <p>QoL: SF-36 (0 to 100).</p>
Notes	Funding was not reported.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	A - Adequate. A computerized randomization schedule, in blocks of 30, was generated at an offsite location, from which participants were informed of their allocation by telephone after completing their baseline assessment
Allocation concealment (selection bias)	Low risk	A - Adequate. A computerized randomization schedule, in blocks of 30, was generated at an offsite location, from which participants were informed of their allocation by telephone after completing their baseline assessment
Blinding (performance bias and detection bias) All outcomes	Unclear risk	B - Unclear. Blinded outcome assessor. Participants reported disability using a questionnaire. The study project manager, who remained blind to participants' group allocation, carried out all outcomes assessments
Incomplete outcome data (attrition bias) All outcomes	Low risk	A - Adequate. The primary statistical analysis was per ITT with a priori planned comparisons

Fransen 2007 (Continued)

Selective reporting (reporting bias)	Low risk	A - Adequate. Trial registered NCT00123994. Key outcomes of participant reported pain and disability were reported
Other bias	Unclear risk	B - Unclear. Co-intervention was unclear.

Hale 2012

Methods	<p>Randomization: computer-generated random numbers.</p> <p>Allocation: concealed by using opaque envelopes (generated and prepared by a person independent of the research project)</p> <p>Outcome assessor: blinded.</p> <p>Losses to follow-up: 4 out of 39 participants (10%).</p> <p>Trial authors did not perform a sufficient ITT analysis.</p>
Participants	<p>Participants responded to public advertisements.</p> <p>Participants had hip or knee OA.</p> <p>Participants had to be aged at least 65 years with at least 1 risk factor for falling according to part 1 of the Falls Risk Assessment Tool, and self-reported OA in the hip or knee, or both, with clinical signs measured using the WOMAC.</p> <p>39 participants were randomized to either water-based exercise intervention (N = 23), or control (N = 16)</p> <p>Aquatic intervention: 74% female; control: 75% female.</p> <p>Mean age (SD): aquatic intervention 73.6 years (1.5), control: 75.7 years (1.1)</p> <p>BMI: not mentioned.</p> <p>Severity: not mentioned.</p>
Interventions	<p>12-week period of water-based exercise classes held twice weekly at the local municipal swimming pool. Class exercise progression was standardized and increased from 20 minutes in the first week up to 60 minutes by week 9. A trained water exercise instructor conducted the exercise classes following a prescribed format. Exercise sessions included warm-up and warm-down exercises and a series of progressively more challenging balance exercises</p> <p>Participants in the control group attended SeniorNet, a community-based computer-skills training programme offered for older adults by older adults. Control participants attended twice weekly for 1-hour sessions during a 12-week period and thus were provided with social interaction seated activity time equivalent to that of the water-based exercise classes</p>
Outcomes	<p>Measured after intervention at 12 weeks.</p> <p>Pain: WOMAC (0 to 20).</p> <p>Disability: WOMAC (0 to 68).</p> <p>QoL: Arthritis Impact Measurement Scale 2 (AIMS2-SF-26) (0 to 104)</p>

Notes	No commercial party with a direct financial interest in the research results supported this article, or has or will confer a benefit on the trial authors or on any organization with which the trial authors are associated	
Risk of bias		
Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	A - Adequate. After baseline testing, participants were randomly allocated by using computer-generated random numbers and concealed opaque envelopes (generated and prepared by a person independent of the research project) into either the intervention or control group
Allocation concealment (selection bias)	Low risk	A - Adequate. After baseline testing, participants were randomly allocated by using computer-generated random numbers and concealed opaque envelopes (generated and prepared by a person independent of the research project) into either the intervention or control group
Blinding (performance bias and detection bias) All outcomes	Unclear risk	B - Unclear. Participants reported disability using a questionnaire. Assessors were blinded to treatment allocation, but not to measurement data from prior assessment points
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	B - Unclear. "All analyses were based on an intention-to-treat basis". However, 4 participants (10%) (3 aquatic and 1 control) drop-out were not analysed according to table 1
Selective reporting (reporting bias)	Low risk	A - Adequate. A large number of outcomes including key outcomes participant reported pain and disability were reported and no key outcomes were missing
Other bias	Low risk	A - Adequate.

Hinman 2007

Methods	<p>Randomization: block randomization, stratified for sex, by computer-generated table of random numbers</p> <p>Allocation: concealed.</p> <p>Blinding: assessor and statistician were blinded.</p> <p>Losses to follow-up: 14.2% at 6 weeks.</p> <p>The trial authors performed an ITT analysis.</p>
Participants	<p>Participants were recruited by advertisements both in the local community and at the local hospital and GPs. Participants had hip or knee OA, or both</p> <p>OA criteria: ACR criteria.</p> <p>71 participants randomized to either aquatic exercise (N = 36), or control (N = 35)</p> <p>Aquatic exercise: 67% female, control: 69% female.</p> <p>Mean age (SD): aquatic exercise: 63.3 years (9.5); control: 61.5 years (7.8)</p> <p>Mean BMI (SD): aquatic exercise: 33.8 (6.5); control: 32.9 (6.6)</p> <p>OA severity: not mentioned.</p>
Interventions	<p>Aquatic exercise: 45 to 60 mins, twice per week, 6 weeks. Individualized exercise programme with focus on balance and isometric leg stance control, taught by an experienced aquatic physical therapist</p> <p>Control: no intervention during the 6-week intervention period. Participants were instructed to continue their usual daily activities and treatment, and not to commence any new exercise programmes. They were offered the intervention following the 6-week intervention period to minimize dropouts</p>
Outcomes	<p>Measured after intervention at 6 weeks.</p> <p>Pain: WOMAC (0 to 500 mm).</p> <p>Disability: WOMAC (0 to 1700 mm).</p> <p>QoL: Assessment of Quality of Life (AQoL) (-0.04 to 1.00).</p>
Notes	<p>No commercial funding. This trial was supported by a National Arthritis and Musculoskeletal Conditions Improvement Grant from the Australian Government Department of Health and Aging</p>

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	A- Adequate. 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
Allocation concealment (selection bias)	Low risk	A - Adequate. Assignment was concealed in sequential opaque envelopes and was revealed by an

Hinman 2007 (Continued)

		independent researcher not involved in eligibility assessment, outcome assessment, or intervention following the baseline assessment
Blinding (performance bias and detection bias) All outcomes	Unclear risk	B - Unclear. Participant reported disability using questionnaire. 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
Incomplete outcome data (attrition bias) All outcomes	Low risk	A - Adequate. Trial authors performed data analyses on an ITT basis. The last observation carried forward was used to impute data missing at reassessment
Selective reporting (reporting bias)	Low risk	A - Adequate. Key outcomes participant reported pain and disability were reported
Other bias	Low risk	A - Adequate. Co-interventions were ok.

Kim 2012

Methods	Randomization: simple randomization using a random number of individuals Allocation: no description of concealment of allocation. Blinding: no blinding stated. Drop-out was 12.5% in both groups and trial authors did not perform an ITT analysis
Participants	Participants were recruited from the a public health centre in South Korea OA criteria: not stated. Knee or hip OA, and were able to walk 70 participants were randomized equally to aquarobic (N = 35) or control (N = 35) Aquatic: 100% women; control: 100% women. Mean age of 68.8 years. Bodyweight: aquatic exercise: 60.9 (9.5) kg; control: 59.2 (5.9) kg OA severity: not mentioned, but disease duration (months) was: aquatic exercise 29.6 (24.1); control 34.5 (38.3)
Interventions	The aquarobic exercise programme consisted of various exercises and aerobics in water 3 times a week in 1-hour sessions, for a total of 36 sessions over 12 weeks. Before aquarobic exercise two educational sessions were carried out Control: nothing but the two educational sessions.

Kim 2012 (Continued)

Outcomes	Measured after intervention at 12 weeks. Pain: visual analogue scale (VAS) (0 to 10). Disability: not measured. QoL: not measured.	
Notes	No commercial funding. This trial was supported by research funds from Chosun University, 2008	
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	A - Adequate. The participants were subjected to simple randomization using a random number of individuals
Allocation concealment (selection bias)	Unclear risk	B - Unclear. No information on allocation concealment.
Blinding (performance bias and detection bias) All outcomes	High risk	C - Inadequate. Participant reported pain and disability using a questionnaire. No information on blinding
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	B - Unclear. Five participants (12.5%) dropped out of the exercise group and 5 participants (12.5%) from the control group. The trial authors did not perform an ITT analysis
Selective reporting (reporting bias)	High risk	C - Inadequate. One key outcome, disability, was missing.
Other bias	Low risk	A - Adequate.

Lim 2010

Methods	<p>Randomization: block randomization (method not mentioned). Stratified, stratum 1: WOMAC < the group median or ≥ the group median; stratum 2: age < 65 and > 65 years</p> <p>Allocation: not clearly mentioned, but apparently concealed allocation (one researcher performed randomization while another evaluated the participants)</p> <p>Blinding: the assessor was blinded.</p> <p>Losses to follow-up: 9.8% at end of treatment</p> <p>The trial authors performed an ITT analysis.</p>	
Participants	<p>Participants who were registered at the rehabilitation, arthritis, and geriatric clinics at the hospital were recruited</p> <p>Participants were both obese (BMI > 25) and had knee OA (Kellgren-Lawrence ≥ 2)</p> <p>75 participants were randomized to either aquatic exercise (N = 26), land-based exercise (N = 25), or control (N = 24)</p> <p>Aquatic exercise: 89% female; land-based: 84% female; control: 88% female</p> <p>Mean age (SD): aquatic exercise: 65.7 years (8.9); land-based: 67.7 years (7.7); control: 63.3 years (5.3)</p> <p>Mean BMI (SD): aquatic exercise: 27.9 (1.5); land-based: 27.6 (1.7); control: 27.7 (2.0)</p> <p>Knee OA severity: Kellgren-Lawrence ≥ 2.</p>	
Interventions	<p>Aquatic exercise: 3 times per week for 8 weeks. 40 mins duration, intensity at 65% of maximal heart rate. 5 mins warm-up and 5 mins cool down. It included both aerobic conditioning and strengthening exercises</p> <p>Land-based exercise: 3 times per week for 8 weeks. 40 mins duration, joint mobilization and strengthening exercise at 40% of 1 RM to 60% of 1 RM, general conditioning and knee-specific exercises. Included 5 mins warm-up and 5 mins cool down</p> <p>Control: home-based quadriceps exercises, behavioural correction of daily activities and lifestyle</p>	
Outcomes	<p>Measured after intervention at 8 weeks.</p> <p>Pain: Brief Pain Inventory (BPI) (an 11-point Numeric Rating Scale (NRS), 0 = no pain)</p> <p>Disability: SF-36 (Physical Component Scale, PCS) (0 to 100)</p> <p>QoL: SF-36 (0 to 100).</p>	
Notes	<p>No commercial funding. This trial was supported by a grant from the Health Promotion Fund 2005, Ministry of Health and Welfare, Republic of Korea. Co-interventions were unclear</p>	
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	B - Unclear. The trial authors did not report the sequence generation method. Participants were randomized to the AQE, LBE, or control groups using a blocked randomization procedure that matched partici-

Lim 2010 (Continued)

		pants according to Western Ontario and McMaster Universities' Osteoarthritis Index (WOMAC) and age
Allocation concealment (selection bias)	Unclear risk	B - Unclear. One researcher performed the randomization and kept the tables of participant allocation and random numbers; the other researcher evaluated the subjects and did not have access to these tables. It is unclear whether the participants were asked to participate before or after the allocation
Blinding (performance bias and detection bias) All outcomes	Unclear risk	B - Unclear. Participant reported pain and disability using a questionnaire. Outcomes evaluators were also blinded to the group assignment of participants
Incomplete outcome data (attrition bias) All outcomes	Low risk	A - Adequate. The trial authors included subjects who dropped out during the interventions in an ITT analysis. For the ITT population, outcome measurements were analysed by using the last observation carried forward method
Selective reporting (reporting bias)	Low risk	A - Adequate. Key outcomes of participant reported pain and disability were reported
Other bias	Low risk	A - Adequate.

Lund 2008

Methods	Randomization: block randomization by opaque envelopes. Allocation: concealed. Blinding: assessor was blinded. Losses to follow-up: 8.8% at 3 months. The trial authors performed an ITT analysis.
Participants	Participants were recruited from outpatient clinics, GPs, and advertisements in the local community OA criteria: ACR criteria and normal CRP and negative rheumatoid factor. Knee 79 participants were randomized to either aquatic exercise (N = 27), land-based exercise (N = 25), or control (N = 27) Aquatic exercise: 83% female; land-based: 88% female; control: 66% female Mean age (SD): aquatic exercise: 65 years (12.6); land-based: 68 years (9.5); control: 70

Lund 2008 (Continued)

	years (9.9) Mean BMI (SD): aquatic exercise: 27.4; land-based: 23.7; control: 26.1 OA severity: not mentioned.	
Interventions	Aquatic exercise: 50 mins, twice per week for 8 weeks. The programme consisted of warm-up, strengthening/endurance, balance, and stretching exercises Land-based: 50 mins, twice per week for 8 weeks. The programme consisted of warm-up, strengthening/endurance, balance, and stretching exercise Control: no intervention during the 8-week intervention period	
Outcomes	Measured after intervention at 8 weeks. Pain: Knee injury and Osteoarthritis Outcome Score (KOOS) (0 to 100) Disability: KOOS (0 to 100). QoL: KOOS Quality of Life (0 to 100).	
Notes	There was no commercial funding. The study was supported by the Oak Foundation, the Research Foundation of the Danish Physiotherapy Association, the Danish Rheumatism Association, the Spies Foundation and the H:S Central Research Fund	
Risk of bias		
Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	B - Unclear. The trial authors did not report sequence generation. The 79 participants were randomized (envelope method (opaque) in blocks of 18 (3 × 6) subjects)
Allocation concealment (selection bias)	Low risk	A - Adequate. Informed consent was given prior to randomization, and the baseline measurements were also taken at this point in order to keep the randomization concealed
Blinding (performance bias and detection bias) All outcomes	Unclear risk	B - Unclear. Two independent physiotherapists, who were both experienced in the measuring methods and blinded to the treatment, took all measurements
Incomplete outcome data (attrition bias) All outcomes	Low risk	A - Adequate. In addition, the trial authors included an ITT analysis, as recommended, using the last observation carried forward methodology, as it tends to produce more conservative estimates independent of drop-out rates between the groups

Lund 2008 (Continued)

Selective reporting (reporting bias)	Low risk	A - Adequate. Trial authors reported key outcomes of participant reported pain and disability
Other bias	Low risk	A - Adequate. Co-interventions not reported.

Patrick 2001

Methods	Randomization: stratified with respect to sex and time of recruitment. The randomization method was not mentioned Allocation: concealment of allocation was unclear. Blinding: no one was blinded. Losses to follow-up: more than 20% (drop-out both at baseline and follow-up) The trial authors performed an ITT analysis, but did not include drop-out in the analyses
Participants	Participants were recruited through advertisements in the local community OA criteria: clinically confirmed OA diagnosis by a physician. Hip or knee 249 participants randomized to either aquatic exercise (N = 125) or control (N = 124) Aquatic exercise: 85.3% female; control: 87.1% female. Mean age (SD): aquatic exercise: 65.7 years; control: 66.1 years BMI: not possible to calculate. OA severity: not mentioned.
Interventions	Aquatic: 45 to 60 mins at least twice per week for 20 weeks. The exercise consisted of joint range-of-motion, and maintenance of muscle strength. Control: followed usual activities, and abstained from new exercise programmes
Outcomes	Measured after intervention at 20 weeks. Pain: Health Assessment Questionnaire (HAQ, pain) (0 to 3) (3 = worst functioning) Disability: HAQ (function) (0 to 3). QoL: quality of well being (QWB) (0 to 1).
Notes	There was no commercial funding. The Centers for Disease Control and Prevention (CDC) (grant number, U 48/CCU00954) funded this trial

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	B - Unclear. The method for sequence generation was not reported. Participants were randomized to the treatment or control group using a stratified randomization process

Patrick 2001 (Continued)

Allocation concealment (selection bias)	Unclear risk	B - Unclear. The method for allocation concealment was not reported.
Blinding (performance bias and detection bias) All outcomes	High risk	C - Inadequate. Participants reported pain and disability using a questionnaire. There was no report on the blinding procedure of participants, personal, and outcome assessor
Incomplete outcome data (attrition bias) All outcomes	Low risk	A - Adequate. Twenty-one participants (17%) in the treatment group and 3 (3%) in the control group did not complete the trial. Even though the trial authors stated an ITT approach, they did not include drop-outs in the analysis The trial authors used an ITT approach to compare treatment and control groups; that is, participants assigned to the aquatic therapy arm who did not attend some or all classes were still included in the intervention group for analysis
Selective reporting (reporting bias)	Low risk	A - Adequate. Key outcomes of participant reported pain and disability were reported
Other bias	Low risk	A - Adequate. Co-interventions were unclear. The participants were paid USD 10, but this did not seem to influence anything but compliance

Stener-Victorin 2004

Methods	Randomization: by sealed, unlabelled envelopes. Allocation: unknown whether or not allocation was concealed. Blinding: no one was blinded. Losses to follow-up: 31% at 3 months. The trial authors performed an ITT analysis.
Participants	Participants were recruited from a waiting list for total hip replacement OA criteria: radiographic changes consistent with OA of the hip and/or pain on load and/or ache during rest. Hip 45 participants randomized to either: 1. aquatic exercise and education (N = 15); 2. patient education (N = 15); 3. electro-acupuncture and education (N = 15) Aquatic exercise: 53.3% female; education: 60% female; electro-acupuncture: 66.7% Mean age: aquatic exercise: 70.3 years; education: 65.5 years; electro-acupuncture: 65.7

	<p>years</p> <p>BMI: not possible to calculate.</p> <p>OA severity: not mentioned.</p>
Interventions	<p>Patient education and aquatic exercise: the educational programme consisted of two group meetings lasting 2 hours each concerning hip anatomy, disease process, and advice on physical activities. Exercise was for 30 minutes, twice per week for 10 weeks. The exercise programme consisted of warm-up, mobility, and strengthening exercises for muscles around the pelvis and stretching exercise</p> <p>Patient education and electro-acupuncture: electro-acupuncture 30 minutes, twice per week for 10 weeks. Acupuncture needles placed locally in the most painful area of the hip.</p> <p>Patient education alone: the educational programme consisted of 2 group meetings lasting 2 hours each concerning hip anatomy, disease process, and advice on physical activities</p>
Outcomes	<p>Measured after intervention at 10 weeks and follow-up at 22 weeks</p> <p>Pain: VAS pain used in relation to three questions: "Do you have any pain related to motion and/or pain on load now?", "Do you have any ache during the day?", "Do you have any ache during the night?" (0 to 100)</p> <p>Disability: Disability rating index (DRI) (0 to 100).</p> <p>QoL: Global Self-rating Index (0 to 10).</p>
Notes	<p>No commercial funding. The Research and Development Unit, Västra Götaland, Sweden supported the trial</p>

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	B - Unclear. The method of sequence generation were not reported. Participants were randomly allocated using sealed, unlabeled envelopes
Allocation concealment (selection bias)	Unclear risk	B - Unclear. It is unclear whether allocation was performed before the decision about participation and baseline measurement or not
Blinding (performance bias and detection bias) All outcomes	High risk	C - Inadequate. No one were blinded in this trial. "The same physiotherapists who gave the treatment made all assessments."
Incomplete outcome data (attrition bias) All outcomes	High risk	C - Inadequate. Five participants (33%) in the treatment group and 8 (53%) in the control group did not complete the trial. The trial authors

Stener-Victorin 2004 (Continued)

		did not perform an ITT analysis
Selective reporting (reporting bias)	Low risk	A - Adequate. Key outcomes participant reported pain and disability were reported
Other bias	Low risk	A - Adequate. Co-intervention unclear.

Wang 2006

Methods	Randomization: method not mentioned. Allocation: whether allocation was concealed is unknown. Blinding: no one was blinded. Losses to follow-up: 10.5% at 12 weeks. The trial authors performed an ITT analysis.
Participants	Participants were recruited from community sources and locations OA criteria: not mentioned. Hip or knee. 42 participants randomized to either aquatic exercise (N = 21), or control (N = 21) Aquatic exercise: 80% female; control: 89% female. Mean age (SD): aquatic exercise: 69.3 (13.3); control: 62.7 (10.7) BMI: not possible to calculate. OA severity: not mentioned.
Interventions	Aquatic exercise: 50 mins, number of times per week not mentioned, for 12 weeks. The exercise programme consisted of warm-up/cool-down, flexibility, endurance, lower and upper body training Control: continued their physical activity level as usual. Offered the intervention following the 12-week period
Outcomes	Measured after intervention at 12 weeks. Pain: VAS: bodily pain (0 to 100). Disability: SF-36 (Physical Functioning) (0 to 3). QoL: not measured.
Notes	The Biobehavioral Nursing Research Training Grant (NINR, T32NR07106-02), the Women's Health Nursing Research Training Grant (NINR, T32NR070-17), the Hester McLaw Nursing Scholarship, and the deTornyay Center for Health Aging Scholarship from the University of Washington, School of Nursing supported this trial

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	B - Unclear. Method for sequence generation were not reported.

Wang 2006 (Continued)

Allocation concealment (selection bias)	Unclear risk	B - Unclear. Method for concealment of allocation were not reported. The participants gave informed consent before randomization, but the time for baseline measurement were not mentioned
Blinding (performance bias and detection bias) All outcomes	High risk	C - Inadequate. No report on blinding procedure of participants, personal, and outcome assessor
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	B - Unclear. One participant (5%) in the treatment group and 3 (14%) in the control group did not complete the study. No ITT approach is stated
Selective reporting (reporting bias)	Low risk	A - Adequate. Key outcomes participant reported pain and disability were reported
Other bias	Low risk	A - Adequate. Co-intervention not described.

Wang 2011

Methods	<p>Randomization: by computer generated random sequence.</p> <p>Allocation: concealed as a researcher not involved in inclusion of participants performed randomization</p> <p>Blinding: outcome assessor blinded, but not participants and therapists</p> <p>Losses to follow-up: approximately 8% in the aquatic exercise group and in the control group</p> <p>The trial authors did not perform an ITT analysis.</p>
Participants	<p>Participants with knee OA were recruited from local community centres and sport centres</p> <p>OA criteria: diagnosed with knee OA by physician assessment based on symptoms and X-ray</p> <p>84 participants were randomly assigned to either the aquatic exercise (N = 28), land-based exercise (N = 28), or the control group (N = 28)</p> <p>Sex: aquatic exercise: 85% female; control: 85% female.</p> <p>Mean age (SD): aquatic exercise: 66.7 (5.6); control: 67.9 (5.9)</p> <p>No differences in education, living arrangement, employment status, and income</p> <p>Mean BMI (SD): aquatic exercise: 26.7 (52.5); control: 26.6 (2.1)</p> <p>No differences in swollen joint, tender joint, and comorbidity</p>
Interventions	<p>A standardized aquatic exercise protocol was developed based on the Arthritis Foundation Aquatics Program (AFAP) instructor's manual. The main components of the programme included a 60-minute flexibility and aerobic training class, 3 times a week for 12 weeks</p>

	The exercise training focused on joints in the trunk, shoulders, arms, and legs and emphasised the muscle groups of the upper and lower limbs, as well as balance and coordination No interventions in the control group.	
Outcomes	Measured after intervention at 12 weeks. Pain: KOOS (subscale pain) (0 to 100). Disability: KOOS (subscale ADL) (0 to 100). QoL: KOOS Quality of Life (0 to 100).	
Notes	No commercial funding. The trial was supported by the National Science Council of Republic of China (NSC, 94-2314-B-227-005)	
Risk of bias		
Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	A - Adequate. A research assistant who did not recruit participants carried out the allocation sequence using a computer-generated random number list
Allocation concealment (selection bias)	Low risk	A - Adequate. Randomized after inclusion by a researcher not involved in inclusion of participants
Blinding (performance bias and detection bias) All outcomes	Unclear risk	B - Unclear. Participant reported pain and disability using questionnaire. Five blinded outcome assessors who were nursing students performed outcome assessment
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	B - Unclear. Two participants (7%) in the treatment group and 2 (7%) in the control group did not complete the trial. The trial authors did not perform an ITT analysis
Selective reporting (reporting bias)	Low risk	A - Adequate. A large number of outcomes were tested and no key outcomes were missing
Other bias	Low risk	A - Adequate.

ACR: American College of Rheumatology.

ACR criteria for the hip joint: age > 40 years, weight-bearing pain, pain relieved by sitting, antalgic gait, decreased painful range of motion, a normal erythrocyte sedimentation rate (ESR), and a negative rheumatoid factor test.

ACR criteria for the knee joint: age > 50 years, knee pain, stiffness < 30 mins, crepitus, bony tenderness, bony enlargement, no palpable warmth, a normal erythrocyte sedimentation rate (ESR), and a negative rheumatoid factor test.

BMI: Body-mass index

EUROQOL: the EuroQoL is a multidimensional health profile developed by the EuroQol Group in 1990 and revised in 1993.

HAQ: Health Assessment Questionnaire.

GP: General Practitioner

ITT: intention-to-treat.

KOOS: Knee injury and Osteoarthritis Outcome Score

PQOL: the Perceived Quality of Life Scale is a generic instrument for assessing perceived quality of life among adults.

OA: osteoarthritis.

QoL: Quality of Life

SD: Standard Deviation

SF-12: Short Form quality of life questionnaire (12 questions)

SF-36: Short Form quality of life questionnaire (36 questions)

VAS: visual analogue scale.

WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index.

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Ahern 1995	Mix of both osteoarthritis (OA) and rheumatoid arthritis (RA) participants
Alexander 2001	Allocation was not randomized. Mix of different participant categories: OA (N = 27), RA (N = 3), fibromyalgia syndrome (FMS) (N = 1), and psoriasis (N = 1)
Belza 2002	Participants had OA in different joints, not just the hip or knee, or both
Borchers 2003	No aquatic exercise intervention. It was not possible to assess the effect of water treatment alone
Bressel 2014	Allocation was not randomized.
Bálint 2007	No exercise intervention.
Cusack 2003	Abstract only.
D'Lima 1996	Aquatic exercise was combined with land exercise. Mix of both OA and RA participants
Davis 2007	Comment on another study (Fransen 2007).
Elkayam 1991	No exercise intervention, only water immersion.
Evcik 2007	No exercise intervention.
Facci 2007	Allocation was not randomized. No control group.
Gaál 2008	No exercise intervention.

(Continued)

Green 1993	Only data on surrogate outcomes.
Guerreiro 2014	Allocation was not randomized.
Guillemín 2001	No exercise intervention (only SPA therapy). Allocation was not randomized
Gyurcsik 2003	Not possible to evaluate the effect on KNEE OA (mix of OA, RA, and FMS). Allocation was not randomized
Hill 1999	No exercise intervention, only water immersion.
Hinman 2005	Abstract for a later publication (Hinman 2007).
Karagülle 2007	No exercise intervention.
Kostopoulos 2000	Only compared two different types of aquatic exercises.
Kovács 2002	No exercise intervention, only immersion.
Lin 2004	Allocation was not randomized.
Mackintosh 2008	Comment on another study (Fransen 2007).
Minor 1989	It is not possible to distinguish between aquatic and non-aquatic exercise/control
Nguyen 1997	Mix of participants with hip, knee, and lumbar OA. There was no exercise intervention, but a mixed modality of spa and balneotherapy
Norton 1999	Study authors only reported effect sizes and gave no standard deviation (SD), thus it was impossible to include the results in the meta-analysis
Pittler 2007	No exercise intervention.
Raspopova 2006	Mix of different treatments.
Rewald, 2015	Allocation was not randomized.
Sato 2007	Mix of different participant groups.
Sherman 2009	No exercise intervention.
Silva 2005	No exercise intervention.
Silva 2008	Only land-based exercise as a control.
Suomi 1997	Mix of participants with RA and OA.
Suomi 2000	Mix of participants with RA and OA.

(Continued)

Suomi 2003	Mix of participants with RA and OA.
Sylvester 1990	No control group, but one group that received hydrotherapy and one group that received land-based exercise and short wave diathermy
Tishler 2004	No exercise, only water immersion.
Vaht 2008	No exercise intervention.
Wallis 2014	Mixed treatment.
Wang 2004	Thesis with the same data as Wang 2006 .
Wyatt 2001	No placebo group. Only land-based exercise as a control.
Yurtkuran 2006	No exercise intervention.

Abbreviations: OA: osteoarthritis; RA: rheumatoid arthritis; FMS: fibromyalgia syndrome; SPA therapy: treatment including water, but not including exercise; SD: standard deviation.

DATA AND ANALYSES

Comparison 1. Aquatic exercise vs control immediately after treatment: knee and hip OA

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Pain	12	1076	Std. Mean Difference (IV, Random, 95% CI)	-0.31 [-0.47, -0.15]
2 Disability	12	1059	Std. Mean Difference (IV, Random, 95% CI)	-0.32 [-0.47, -0.17]
3 Quality of life	10	971	Std. Mean Difference (IV, Random, 95% CI)	-0.25 [-0.49, -0.01]

Comparison 2. Aquatic exercise vs control immediately after treatment: knee OA

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Pain	3	150	Std. Mean Difference (IV, Random, 95% CI)	-0.28 [-0.69, 0.12]
2 Disability	3	150	Std. Mean Difference (IV, Random, 95% CI)	-0.25 [-0.57, 0.07]
3 Quality of life	3	150	Std. Mean Difference (IV, Random, 95% CI)	-0.54 [-1.28, 0.19]

Comparison 3. Aquatic exercise vs control immediately after treatment: hip OA

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Pain	1		Std. Mean Difference (IV, Random, 95% CI)	Totals not selected
2 Disability	2	68	Std. Mean Difference (IV, Random, 95% CI)	-1.16 [-3.11, 0.78]
3 Quality of life	1	17	Std. Mean Difference (IV, Random, 95% CI)	-1.81 [-1.00, -0.62]

Comparison 4. Aquatic exercise vs control at follow-up: knee and hip OA

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Pain	3	381	Std. Mean Difference (IV, Random, 95% CI)	-0.30 [-0.92, 0.32]
2 Disability	3	377	Std. Mean Difference (IV, Random, 95% CI)	-0.32 [-0.83, 0.20]
3 Quality of life	3	381	Std. Mean Difference (IV, Random, 95% CI)	-0.15 [-0.64, 0.34]

Comparison 5. Aquatic exercise vs control at follow-up: knee OA

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Pain	1		Std. Mean Difference (IV, Random, 95% CI)	Totals not selected
2 Disability	1		Std. Mean Difference (IV, Random, 95% CI)	Totals not selected
3 Quality of life	1	54	Std. Mean Difference (IV, Random, 95% CI)	-0.11 [-0.65, 0.42]

Comparison 6. Aquatic exercise vs control at follow-up: hip OA

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Pain	1		Std. Mean Difference (IV, Random, 95% CI)	Totals not selected
2 Disability	1		Std. Mean Difference (IV, Random, 95% CI)	Totals not selected
3 Quality of life	1	17	Std. Mean Difference (IV, Random, 95% CI)	-1.09 [-2.15, -0.04]

Comparison 7. Adverse events

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Adverse events	13	1190	Risk Ratio (M-H, Fixed, 95% CI)	1.25 [0.98, 1.60]

WHAT'S NEW

Last assessed as up-to-date: 28 April 2015.

Date	Event	Description
28 April 2015	New search has been performed	We restricted the inclusion criteria to aquatic exercise compared to a control group, and not compared to other interventions. Thus we excluded two trials that compared aquatic exercise to another intervention (Wang 2004 ; Wyatt 2001). We amended the inclusion criteria for types of studies from both randomized controlled trials (RCTs) and quasi-RCTs to RCTs only As pain and disability is recommended as the main outcome for people with knee and hip osteoarthritis (Bellamy 1997), we focused only on pain and disability in this

(Continued)

		Cochrane review update We have amended the order of review authors and included one new review author, CB Juhl
28 April 2015	New citation required but conclusions have not changed	Due to the new literature search, we included nine new trials in this review update (Arnold 2008 ; Fransen 2007 ; Hale 2012 ; Hinman 2007 ; Kim 2012 ; Lim 2010 ; Lund 2008 ; Wang 2006 ; Wang 2011), and excluded two formerly included trials. Thus the number of participants increased from 800 to 1186 and the number of included studies increased from 6 to 13. However, the conclusions did not change

HISTORY

Protocol first published: Issue 4, 2005

Review first published: Issue 4, 2007

Date	Event	Description
21 May 2014	New search has been performed	We converted to a new review format. C006-R

CONTRIBUTIONS OF AUTHORS

Bartels EM, Juhl CB, Christensen R, Hagen KB, Danneskiold-Samsøe B, Dagfinrud H, and Lund H contributed to the review content.

Bartels EM, Juhl CB, Christensen R, Hagen KB, Dagfinrud H, and Lund H assisted with the methodology.

Juhl CB, Christensen R, Hagen KB, and Lund H performed and interpreted the statistical analyses.

DECLARATIONS OF INTEREST

Christensen R, Danneskiold-Samsøe B, and Lund H were co-authors of the [Lund 2008](#) trial. Otherwise none known. EM Bartels has no known conflicts of interests. CB Juhl has no known conflicts of interests, R Christensen has no known conflicts of interests, H Dagfinrud has no known conflicts of interests, KB Hagen has no known conflicts of interests, B Danneskiold-Samsøe has no known conflicts of interests, and H Lund has no known conflicts of interests.

SOURCES OF SUPPORT

Internal sources

- Oak Foundation, Denmark.
- Copenhagen University Library, Denmark.

External sources

- No sources of support supplied

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

We have made the following changes since the Cochrane protocol was published ([Bartels 2005](#)):

1. Authorship: we added CB Juhl to the list of review authors.
2. In order to secure the highest possible quality of included studies, we only included randomized controlled trials (RCTs) and no quasi-RCTs.
3. In order to focus the systematic review, we restricted the research question to compare aquatic exercise vs no intervention, thus we only included trials with a control group of no specific intervention, i.e. usual care, education, social attention, telephone call, etc. That led to an exclusion of two trials included in the first version of this Cochrane review ([Bartels 2007](#)): we excluded [Wang 2004](#) because it is a PhD thesis and [Wang 2006](#) is a scientific paper about the same trial. We excluded [Wyatt 2001](#) because it was only a comparison between land-based and aquatic exercise.
4. Based upon the recommendations from OMERACT ([Bellamy 1997](#)), we only included trials using pain, disability, or radiographics as outcomes.
5. In order to improve the literature search, we also checked the Cochrane's Central Register of Controlled Trials (CENTRAL) database.
6. Acknowledging the difficulties to reach all study authors, we chose not to contact any authors of the included trials to identify any additional published or unpublished data.
7. In accordance with the Cochrane recommendations, we based the 'Risk of bias' assessment on the 'Risk of bias' tool from the *Cochrane Handbook of Systematic Reviews of Interventions* ([Higgins 2011](#)).
8. We were unable to make a clear distinction between the major types of aquatic exercise, thus we did not perform any analyses of subcategories involving type of interventions.
9. Since the publication of the Cochrane protocol, [Juhl 2012](#) has presented a hierarchy of outcomes. Thus, when an included trial reported more than one pain or disability outcome, we based our choice upon the outcome hierarchy suggested by [Juhl 2012](#).
10. Since there are a large number of different outcomes covering pain and disability, we performed all meta-analyses using random-effect models and only presented standardized mean difference (SMD) values.
11. In accordance with Cochrane recommendations, we evaluated heterogeneity in all analyses (i.e. both Cochran's Q test and the I² statistic test) ([Higgins 2011](#)).
12. In accordance with Cochrane recommendations, we assessed the quality of the evidence according to the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach ([Higgins 2011](#)).

INDEX TERMS

Medical Subject Headings (MeSH)

*Water; Balneology; Chronic Disease; Exercise; Exercise Therapy [*methods]; Hydrotherapy [methods]; Osteoarthritis, Hip [*therapy]; Osteoarthritis, Knee [*therapy]; Quality of Life; Randomized Controlled Trials as Topic; Swimming

MeSH check words

Aged; Female; Humans; Male