Z Rheumatol 2015 · 74:543–552
DOI 10.1007/s00393-014-1559-9
Published online: 19. Februar 2015

Redaktion
U. Müller-Ladner, Bad Nauheim
U. Lange, Bad Nauheim

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Effectiveness of aquatic exercise for treatment of knee osteoarthritis

Systematic review and meta-analysis

Background

Osteoarthritis (OA) is the most prevalent rheumatic disease, causing degenerative changes in cartilage and the periarticular area [1]; the knee is the most commonly affected joint. The most prominent symptom of knee OA is pain, while reduction in quality of life (QOL), loss of physical function, and muscle weakness are also often associated [2, 3]. In addition, loss of productivity and personal economic strain are associated with ongoing care and disease management [4]. Therapeutic exercise is recommended in numerous guidelines as a nonpharmacologic treatment for knee OA [5, 6, 7].

Aquatic exercise, which utilizes the characteristics of water to promote health, has a long history and is becoming more popular. Motion against water resistance results in increased muscle tone, power development, and improved endurance [8]. Water also reduces weight bearing due to the property of buoyancy [9]. The heating effect of water temperature has been reported to ease soft tissue contracture, reduce pain, and relieve muscle spasms and fatigue [8, 10, 11]. Since aquatic exercise is easier on the body, the practice of exercise feels better and is perceived to be more enjoyable—and pleasurable exercise appears to improve QOL [12, 13].

Several previous systematic reviews have summarized the effects of aquatic exercise, but they either included mixed populations (e.g., including individuals with chronic diseases, such as hip OA) [14, 15, 16, 17] or were nonrandomized controlled trials [18]. However, existing clinical practice guidelines uniformly recommend aquatic exercise for treatment of knee OA [5, 19].

It is important to verify the evidence for aquatic exercise's effect on improving physical function, QOL, and pain in individuals with knee OA. A systematic review of all randomized controlled trials (RCTs) to date would determine whether aquatic exercise is effective in improving outcomes in individuals with knee OA.

Methods

Criteria for considering studies for this review

Types of studies

Studies were eligible if they were RCTs.

Types of participants

Patients with primary knee OA were eligible. Diagnosis had to meet the classification criteria of the American College of Rheumatology [20, 21]. No further restrictions were made regarding disease duration or intensity.

Types of interventions

Studies that compared aquatic exercise to no treatment, usual care, or any other active treatment were eligible. All types of exercise developed in a therapeutic/heated indoor pool were eligible. Co-interventions other than exercise in a pool were allowed.

Types of outcome measures

According to the core set of outcome measures defined by Outcome Measures in Rheumatology Clinical Trials [22], studies were eligible if they assessed at least one of the following outcome measures: pain, physical function, or joint stiffness. If available, data on QOL and safety served as secondary outcome measures.

Search methods for identification of studies

Two authors (Meili Lu and Wenting Wang) independently completed a search of electronic databases. The following electronic databases were searched from their commencement through to June 2014: PubMed, the Cochrane Library, Embase, CAMbase, and the Web of Science. The literature search was conducted around search terms for aquatic exercise and knee OA, and adapted for each database as necessary. For PubMed, the search strategy was as follows: "(balneology [MeSH Terms] OR balneology [All Fields] OR balneotherapy [All Fields]) OR (hydrotherapy [MeSH Terms] OR hydrotherapy [All Fields] OR aquatic exercise [All Fields] OR pool exercise [All Fields] OR water exercise [All Fields]) AND (knee osteoarthritides [All Fields] OR knee osteoarthritis [All Fields] OR osteoarthritides of knees [All Fields] OR osteoarthritis of knees [All Fields] OR osteoarthritis, knee [MeSH Terms])".

For further articles, the reference lists of articles were searched. There was no restriction on language.

The authors are grateful to the State Administration of Traditional Chinese Medicine for funding this study (No. 201307004).

Data collection and analysis

Selection of studies

After removal of duplicate records, two authors (Yingjie Zhang and Zhen He) independently screened the title, abstract, keywords, and publication type of all records obtained from the described searches. Disagreement or uncertainty was resolved by discussion with a third author (Youxin Su). The potentially eligible studies were obtained by hardcopy and read in detail, and those deemed eligible were included in the systematic review and meta-analysis. Studies in which characteristics were not clearly described or data were missing, the authors of the study were contacted for clarification.

Assessment of risk of bias in included studies

In order to ensure that variation was not caused by the study design or execution, risk of bias was assessed independently by two authors (Lu Sheng and Changyan Liu) using the Cochrane Handbook for Systematic Reviews of Interventions [23]. The domains recommended for assessing risk of bias in studies included selection bias, performance bias, detection bias, attrition bias, reporting bias, and other bias. Studies that met low risk of bias in all key domains were rated as having low risk of bias, those that met unclear risk of bias in one or more key domains were rated as having unclear risk of bias, and those that met high risk of bias in one or more key domains were rated as having high risk of bias. Where study data were inconclusive, trial authors were contacted for further details. Uncertainty or disagreement was resolved by discussion with a third author (Feiwen Liu).

Analyses and presentation

Studies were stratified in subgroups according to:

1. type of intervention (e.g., aerobic exercise, range of motion (ROM) exercise, strength exercise, and balance exercise),
2. duration of follow-up (e.g., at the end of treatment and 3, 6, and 12 months after treatment) and
3. primary outcome measures, such as pain and physical function.

In each group, the analysis was divided into aquatic exercise versus nonexercise, or aquatic exercise versus another active type of exercise.

Meta-analysis focused on outcome measures concerning improvement in the following aspects: pain, physical function, stiffness, QOL, and mental health.

Data extraction

Two authors (Yanan Li and Yiru Wang) independently extracted data on study characteristics, such as participants, interventions, cointerventions, control conditions, outcome measures, and results. Uncertainty or disagreement was resolved by discussion with a third author (Ziyi Zhang).

When choosing outcome measures for analysis, we decided on the following priority lists if more than one measured parameter in a category was present in the study:

- The list of pain measures was as follows (in descending order): visual analog scale (VAS pain), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC pain), Knee injury and Osteoarthritis Outcome Score (KOOS pain), Short Form-36 (SF-36 pain), Short Form-12 (SF-12 pain), and Arthritis Impact Measurement Scale (AIMS pain).
- The list of physical function measures was as follows (in descending order): WOMAC function, Health Assessment Questionnaire (HAQ function), KOOS activities of daily living (ADL), SF-36 physical function, and Arthritis Self-Efficacy Questionnaire (ASEQ function).
- The list of stiffness measures was as follows (in descending order): WOMAC stiffness, ROM, and KOOS stiffness.
- The list of QOL measures was as follows (in descending order): SF-36 QOL, KOOS QOL, AIMS-2 affect, and Quality of Well-Being Scale (QWB).
- The list of mental health measures was as follows (in descending order): SF-36 mental, SF-12 mental, AIMS-2 satisfaction, and ASEQ mental.

Measures of treatment effect

If at least two trials of comparable aquatic exercise protocols and outcome measures existed, meta-analysis was conducted using Review Manager 5.1 software (The Cochrane Collaboration, Software Update, Oxford) [24]. Standardized mean differences (SMD) with 95% confidence intervals (CI) were calculated to assess intervention effects. Judgment of overall effect size was based on Cohen's categories: SMD of 0.2–0.5 was considered a small effect, SMD of 0.5–0.8 a moderate effect, and SMD >0.8 a large effect [25].

Grades of evidence were judged using criteria from the Cochrane Back Review Group as follows [26]: Strong evidence: consistent findings among multiple RCTs with low risk of bias; moderate evidence: consistent findings among multiple high-risk RCTs and/or one low-risk RCT; limited evidence: one RCT with high risk of bias; conflicting evidence: inconsistent findings among multiple RCTs; or no evidence: no RCTs.

Assessment of heterogeneity

Statistical heterogeneity between studies was tested by performing a χ-squared test. I^2>25%, I^2>50%, and I^2>75% were defined to indicate moderate, substantial, and considerable heterogeneity, respectively [23]. If the P-value of this test was <0.1, an I^2 test was performed. If the I^2 test showed a value >50%, we considered this to indicate substantial heterogeneity and a random effects model was performed.

Results

Study selection

A total of 1048 papers were identified from the database searches, 255 of which were duplicates (**Fig. 1**). Of the remaining 793 papers, 760 were excluded based on title or abstract; therefore, 33 full-text articles were assessed for eligibility [8, 11, 13, 27-56]. Twenty-seven full-text articles were excluded because they involved mixed patient samples [8, 13, 33, 44, 46, 48, 49], were not RCTs [27, 28, 30, 35, 40, 45, 50, 55], had no clinical outcomes [31, 42, 53], did not involve exercise (only water immersion) [32, 39, 41, 47, 51, 52, 54], or were only a protocol [29] or abstract [34]. Six studies involving 398 participants were included in qualitative and quantitative analyses [11, 36, 37, 38, 43, 56].

Abstract · Zusammenfassung

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Effectiveness of aquatic exercise for treatment of knee osteoarthritis. Systematic review and meta-analysis

Abstract

Objective. This paper presents a systematic review and meta-analysis of the effectiveness of aquatic exercise for treatment of knee osteoarthritis (OA).

Methods. PubMed, the Cochrane Library, Embase, CAMbase, and the Web of Science were screened through to June 2014. Only randomized controlled trials (RCTs) comparing aquatic exercise with control conditions were included. Two authors independently selected trials for inclusion, assessed the included trials, and extracted data. Outcome measures included pain, physical function, joint stiffness, quality of life (QOL), and safety. Pooled outcomes were analyzed using standardized mean difference (SMD).

Results. There is a lack of high quality studies in this area. Six RCTs (398 participants) were included. There was moderate evidence for a moderate effect on physical function in favor of aquatic exercise immediately after the intervention, but no evidence for pain or QOL when comparing aquatic exercise with nonexercise. Only one trial reported 3 months of follow-up measurements, which demonstrated limited evidence for pain improvement with aquatic exercise and no evidence for QOL or physical function when comparing aquatic exercise with nonexercise. There was limited evidence for pain improvement with land-based exercise and no evidence for QOL or physical function, when comparing aquatic exercise with land-based exercise according to follow-up measurements. No evidence was found for pain, physical function, stiffness, QOL, or mental health with aquatic exercise immediately after the intervention when comparing aquatic exercise with land-based exercise. Two studies reported aquatic exercise was not associated with serious adverse events.

Conclusion. Aquatic exercise appears to have considerable short-term benefits compared with land-based exercise and nonexercise in patients with knee OA. Based on these results, aquatic exercise is effective and safe and can be considered as an adjuvant treatment for patients with knee OA. Studies in this area are still too scarce and too short-term to provide further recommendations on how to apply this therapy.

Keywords

Randomized controlled trial · Balneology · Pain · Physical function · Quality of life

Wirksamkeit von Wassergymnastik bei Kniegelenksarthrose. Systematische Übersicht und Metaanalyse

Zusammenfassung

Ziele. In der vorliegenden systematischen Übersicht und Metaanalyse wurde die Wirksamkeit von Wassergymnastik in der Behandlung der Kniegelenksarthrose untersucht.

Methoden. PubMed, die Cochrane Library, Embase, CAMbase und das Web of Science wurden bis Juni 2014 durchsucht. Eingeschlossen wurden nur randomisierte, kontrollierte Studien (RCT), in denen Wassergymnastik mit Kontrollbedingungen verglichen wurde. Zwei Autoren schlossen unabhängig Studien ein, prüften diese und extrahierten Daten. Zu den Studienendpunkten gehörten Schmerz, körperliche Funktionsfähigkeit, Gelenksteifigkeit, Lebensqualität und Sicherheit. Die gepoolten Ergebnisse wurden anhand standardisierter Mittelwertdifferenzen (SMD) analysiert.

Ergebnisse. Es mangelt an qualitativ hochwertigen Studien zur beschriebenen Thematik. Sechs RCT mit 398 Teilnehmern wurden eingeschlossen. Die Analyse ergab eine mäßige Evidenz dafür, dass Wassergymnastik verglichen mit dem Verzicht auf Bewegungsübungen einen moderaten Effekt auf die körperliche Funktionsfähigkeit unmittelbar nach der Anwendung hat; in Bezug auf Schmerz oder Lebensqualität ließ sich dagegen keine Wirkung belegen. Nur in einer Studie wurden für 3 Monate Follow-up-Messungen durchgeführt. Diese ergaben eine begrenzte Evidenz für eine Schmerzbesserung bei Wassergymnastik und keinen Beleg für einen Effekt auf die Lebensqualität oder körperliche Funktionsfähigkeit, wenn Wassergymnastik mit dem Verzicht auf Bewegungsübungen verglichen wurde. Gemäß den Follow-up-Messungen gab es eine eingeschränkte Evidenz für eine Schmerzbesserung bei Trockengymnastik im Vergleich zu Wassergymnastik, hinsichtlich der Lebensqualität und körperlichen Funktionsfähigkeit fand sich keine Evidenz. In Bezug auf Schmerz, die körperliche Funktionsfähigkeit, Steifigkeit, Lebensqualität und psychische Verfassung fand sich kein Effekt der Wassergymnastik direkt nach Anwendung im Vergleich zu Trockengymnastik. In zwei Studien war angegeben, dass Wassergymnastik nicht mit schweren unerwünschten Ereignissen verbunden war.

Schlussfolgerungen. Verglichen mit Trockengymnastik und dem Verzicht auf Bewegungsübungen scheint Wassergymnastik kurzzeitig von beträchtlichem Nutzen für Patienten mit Kniegelenksarthrose zu sein. Auf der Grundlage dieser Ergebnisse ist die Methode wirksam und sicher. Sie kann als unterstützende Maßnahme bei Kniegelenksarthrose angesehen werden. Da es in diesem Themenbereich noch immer zu wenige Studien gibt und die Studiendauer zu knapp bemessen ist, sind weitergehende Empfehlungen zur Anwendung der Wassergymnastik nicht möglich.

Schlüsselwörter

Randomisierte, kontrollierte Studie · Balneologie · Schmerz · Körperliche Funktionsfähigkeit · Lebensqualität

Study characteristics

Characteristics of the included studies, including samples, interventions, outcome measures, and results, are presented in ◘ **Tab. 1**.

Setting and participant characteristics

Trials originated from the United States [56], Denmark [43], Taiwan [36], Brazil [11], Thailand [38], and Korea [37]. Patients were recruited from outpatient clinics [11, 37, 38, 43, 56] or local community centers [36]. Subjects were diagnosed according to criteria of the American College of Rheumatology (ARC) [11, 43] with clinical [11] and radiographic [11, 36, 37]

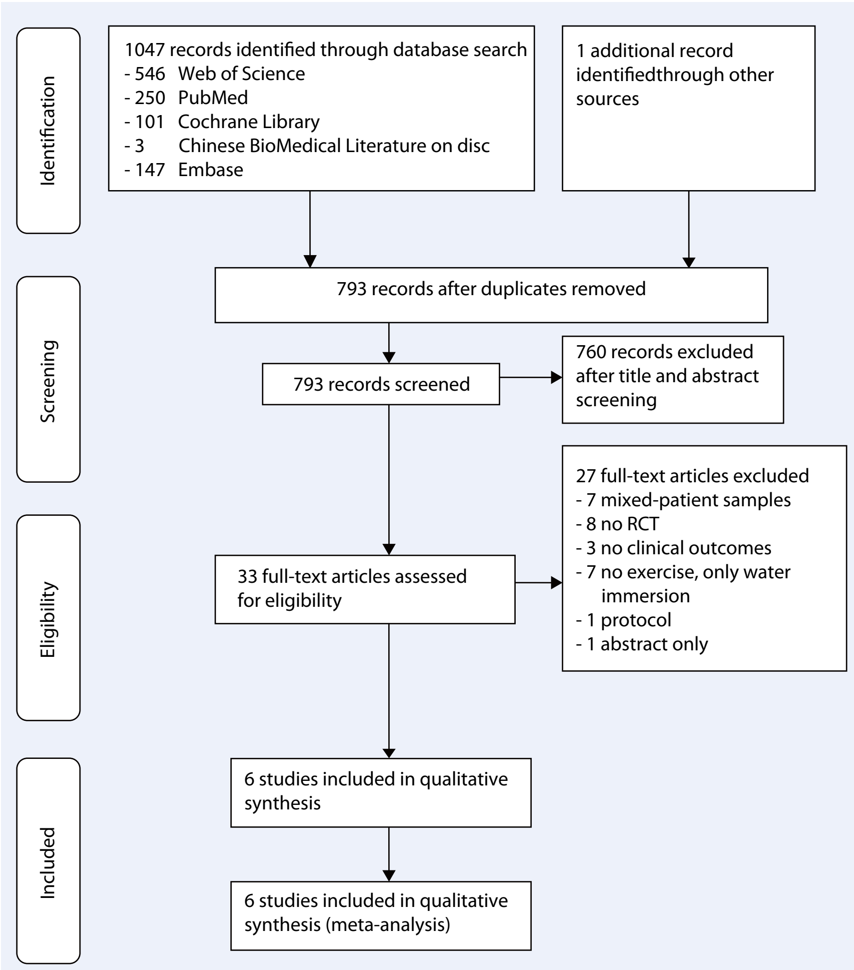


Fig. 1 ▲ Flowchart of the results of the literature search

confirmation of primary [38, 43] and moderate [38, 56] knee OA. In one study, knee pain ranging from 30 to 90 mm on a VAS [11] was also an inclusion criterion. Patients were excluded if they underwent arthroscopic surgery within 1 year [38], had inflammatory joint disease [37, 43, 56], had skin disease [11, 37], received knee joint replacement [36, 43], had received intra-articular corticosteroid injection in the past 30 days [36] or 3 months [11, 38], practiced regular physical activity [11, 36], or had received physical therapy intervention for their knee in the preceding 3 [38] or 6 months [11].

On average, patients were aged in their 60s or 70s, and the majority were female. Two studies reported adverse events [36, 43]. Data on ethnicity were available in two studies [36, 43].

Intervention characteristics

Aquatic exercise lasted 6 [38, 56], 8 [37, 43], 12 [36], or 18 weeks [11], with sessions offered two- [43] or three-times [11, 36, 37, 56] per week. Aquatic exercise included stretching [11, 38, 43], fast walking [37, 38], strengthening [11, 37, 43], and/or aerobic training [36, 37].

Control interventions included land-based exercise [11, 36, 37, 38, 43, 56], following treatment as usual [37], or home-based exercise [36].

Patients received nonsteroidal inflammatory drugs as a cointervention in two studies [11, 38].

Outcome measures

Pain was assessed in five studies; four used a VAS [11, 38, 43, 56] and one used the KOOS pain scale [36]. Physical function was assessed in three studies; two used the KOOS ADL scale [36, 43] and one used the WOMAC function scale. Stiffness was assessed in three studies; two used ROM and one used the WOMAC stiffness scale. Three studies measured QOL using the KOOS QOL scale [36, 38, 43].

Risk of bias in included studies

All studies had a high risk of bias due to nonblinding of participants (◘ **Fig. 2** and ◘ **Fig. 3**). All studies had a low risk of reporting bias and attrition bias. All studies also had a low risk of detection bias, with only Yennan et al. [38] not reporting further details regarding assessor blinding. The risk of selection bias was mixed; only one study reported allocation concealment [43] and four studies conducted random sequence generation [11, 36, 37, 43].

Effect of interventions

Aquatic exercise vs. land-based exercise: measurements immediately after exercise intervention

Meta-analysis revealed there was no significant effect on physical function (SMD 0.31; 95% CI −0.01–0.63), pain intensity (SMD −0.25; 95% CI −0.74–0.24), stiffness (SMD −0.15; 95% CI −0.47–0.17), or QOL (SMD 0.26; 95% CI −0.05–0.58) in favor of aquatic exercise immediately after the intervention (◘ **Fig. 4**). Only one study reported mental health measurement and there was no evidence for an effect [37].

Aquatic exercise vs. land-based exercise: follow-up measurements

Only one study reported 3 months of follow-up measurements [43]. No evidence for physical function or QOL was found for aquatic exercise after 3 months of treatment. There was limited evidence for pain improvement based on follow-up measurements for land-based exercise when compared with aquatic exercise.

Aquatic exercise vs. nonexercise: measurements immediately after exercise intervention

There was moderate evidence for a moderate effect on physical function (SMD −0.55; 95% CI −0.94 to −0.16) in favor of aquatic exercise immediately after

Tab. 1 Characteristics of the included studies

Author, publication date	Sample size	No. of groups	Gender (F/M)	Mean age (years) ± SD	Inclusion criteria	Treatment group: intervention program length, duration, frequency	Control group: intervention program length, duration, frequency	Outcome assessment	Outcome measures 1) Pain 2) Physical function 3) Stiffness 4) QOL 5) Mental heath 6) Safety	Result[a] 1) Pain 2) Physical function 3) Stiffness 4) QOL 5) Mental Health 6) Safety
Wyatt et al. 2001	46 AE: 23 LB: 23	2	NA	NA	Age 45–70 years moderate osteoarthritis of the knee no other low-extremity pathologies	3-times per week for 6 weeks, exercise in a therapeutic pool of 5-foot depth at 90°F	LB: 3-times per week for 6 weeks, exercise in a gym	Pretest–posttest (week 6)	1) VAS 2) NA 3) Knee ROM 4) NA 5) NA 6) NA	Posttest: 1) AE > LB 2) NA 3) NS 4) NA 5) NA 6) NA
Lund et al. 2008	79 AE: 27 LB: 25 non-exercise: 27	3	AE: 22/5 LB: 22/3 non-exercise: 18/9	AE: 65±12.6 Nonexercise: 70±9.9	Primary knee osteoarthritis (according to the ACR), C-creative protein within the reference range, negative rheumatoid factor	Session of 50 min, 2 sessions per week for 8 weeks, exercise in a pool at 92.3°F, follow the treatment as usual at the same time	LB: session of 50 m, 2 sessions per week for 8 weeks, follow the treatment as usual at the same time; non-exercise: follow the treatment as usual	Pretest–posttest (week 8) follow-up (week 20)	1) VAS 2) KOOS ADL 3) NA 4) KOOS QOL 5) NA 6) Adverse events	Posttest: 1) NS 2) NS 3) NA 4) NS 5) NA 6) AE > LB follow-up: 1)LB > nonexercise 2) NS 3) NA 4) NS 5) NA 6) NR
Wang et al. 2011	84 AE: 28 LB: 28 nonexercise: 28	3	NR	AE: 66.7±5.6 LB: 68.3±6.4 nonexercise: 67.9±5.9	Age over 55 years diagnosed with knee osteoarthritis by physician assessment based on symptoms and X-ray, consented to participate	Session of 60 min, 3-times per week for 12 weeks, exercise in a public swimming pool at 86°F	LB: session of 60 min, 3-times per week for 12 weeks; non-exercise: NR	Pretest–posttest (week 12)	1) KOOS pain 2) KOOS ADL 3) Knee ROM 4) KOOS QOL 5) NA 6) Adverse events	Posttest: 1) AE > nonexercise, LB > nonexercise 2) AE > nonexercise, LB > nonexercise 3) AE > nonexercise, LB > nonexercise 4) AE > nonexercise, LB > nonexercise 5) NA 6) NS

Tab. 1 Characteristics of the included studies (continued)

Author, publication date	Sample size	No. of groups	Gender (F/M)	Mean age (years) ± SD	Inclusion criteria	Treatment group: intervention program length, duration, frequency	Control group: intervention program length, duration, frequency	Outcome assessment	Outcome measures 1) Pain 2) Physical function 3) Stiffness 4) QOL 5) Mental heath 6) Safety	Result[a] 1) Pain 2) Physical function 3) Stiffness 4) QOL 5) Mental Health 6) Safety
Silva et al. 2008	64 WB: 32 LB: 32	2	WB: 30/2 LB: 29/3	WB: 5 9±7.6 LB: 59±6.08	Clinical and radiographic diagnosis of knee osteoarthritis (according to the ACR), knee pain ranging from 30 to 90 mm on a VAS, consented to participate	Session of 50 m, 3-times per week for 18 weeks, exercise in a 120-cm deep pool at 89.6°F	LB: session of 50 min, 3 times per week for 18 weeks, exercise in a room with mats and a walkway	Pretest–posttest (week 18)	1) VAS 2) no clinical outcomes 3) no clinical outcomes 4) no clinical outcomes 5) NA 6) NA	Posttest: 1) WB > LB 2) no clinical outcomes 3) no clinical outcomes 4) no clinical outcomes 5) NA 6) NA
Lim et al. 2010	75 AE: 26 LB: 25 nonexercise: 24	3	AE: 23/3 LB: 21/4	AE: 65.7±8.9 LB: 67.7±7.7 nonexercise: 63.3±5.3	50 years or older, more than 25 kg/m² BMI, abdominal circumference more than 90 cm for men and 85 cm for women, Kellgren–Lawrence grade 2 or higher in radiologic assessments	Session of 40 min, 3-times per week for 8 weeks, exercise in aquatic gym with 115-cm deep water at 93.2°F	LB: session of 40 min, 3-times per week for 8 weeks, exercise in the gym next to aquatic gym; nonexercise: home-based exercise	Pretest–posttest (week 8)	1) no clinical outcomes 2) no clinical outcomes 3) no clinical outcomes 4) no clinical outcomes 5) SF-36 mental 6) Adverse events	Posttest: 1) no clinical outcomes 2) no clinical outcomes 3) no clinical outcomes 4) no clinical outcomes 5) NS 6) NR
Yennan et al. 2010	50 AE: 25 LB: 25	2	NR	AE: 65.6±4.9 LB: 66.4±4.4	Age between 60 and 75 years, mild to moderate degree primary knee osteoarthritis, BMI between 20 and 30 kg/m², no regular strengthening or aerobic exercise	Session of 65 min for 6 weeks, not reported how many times per week, exercise in the therapeutic pool with waist-high water level and ambient temperature	LB: session of 65 min for 6 weeks, not reported how many times per week, exercise on normal floor at home	Pretest–posttest (week 6)	1) VAS 2) WOMAC function 3) WOMAC stiffness 4) KOOS QOL 5) NA 6) NA	Posttest: 1) AE > LB 2) NS 3) NS 4) NS 5) NA 6) NA

AE aquatic exercise, *LB* land-based exercise, *WB* water-based exercise, *NR* not reported, *NA* not assessed, *NS* not significant, *F/M* female/male, *ROM* range of motion, *VAS* Visual Analog Scale, *WOMAC* Western Ontario and Mc, Universities Osteoarthritis Index, *KOOS* Knee injury and Osteoarthritis Outcome Score, *QOL* quality of life, *BMI* body mass index, *ACR* American College of Rheumatology, *SD* standard deviation[a]Significantly better than.

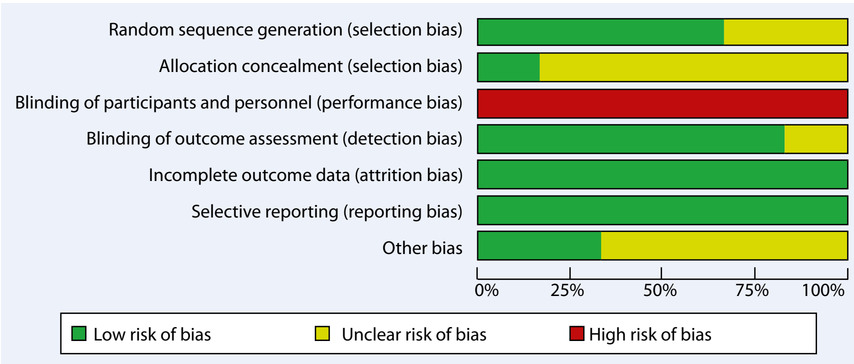


Fig. 2 ▲ Risk of bias graph: review authors' judgments on each risk of bias item presented as percentages across all included studies

Fig. 3 ◀ Risk of bias summary: review authors' judgments on each risk of bias item for each included studies

the intervention. No significant effect was found for pain (SMD –1.16; 95% CI –3.03–0.71) or QOL (SMD –0.21; 95% CI –0.59–0.18; **Fig. 4**). No evidence was found for stiffness [36] or mental health [37].

Aquatic exercise vs. nonexercise: follow-up measurements

Only one study reported 3 months of follow-up measurements [43]. No evidence for physical function or QOL was found for aquatic exercise after 3 months of treatment. There was limited evidence for pain improvement based on follow-up measurements for aquatic exercise when compared with nonexercise strategies.

Discussion

The purpose of this review was to evaluate the curative efficacy of aquatic exercise in patients with knee OA. Knee OA is more prevalent in the elderly, and is associated with large societal and economic burdens. According to previous reports, elderly Chinese women have a higher prevalence of knee OA than Caucasian women [57, 58]. Interventions for knee OA that can stop or slow disease progression are of great importance—from both economic and patient QOL-related viewpoints.

Because of the intervention properties of aquatic exercise, blinding of subjects and executors is impossible. The awareness of being treated may provide a bias when compared to a control group not exposed to treatment. Since both aquatic and land-based exercises in this review involved active treatment and attention from executors, one must assume there is no such bias effect. We identified all studies with a high risk of performance bias (**Fig. 2 and** **Fig. 3**) and found very few high-quality studies acceptable for meta-analysis. Furthermore, descriptions of adverse events and withdrawals were generally insufficient. All studies had more than 80% attendance, however, which is very good for a therapy that demands out-of-house treatment several times a week.

At the end of treatment, meta-analysis revealed there was no significant difference in effects on physical function, pain intensity, stiffness, or QOL between aquatic and land-based exercises immediately after the interventions. The same observation was made for physical function and QOL based on follow-up measurements in one included study; however, pain improvement was superior with land-based exercise compared with aquatic exercise [43].

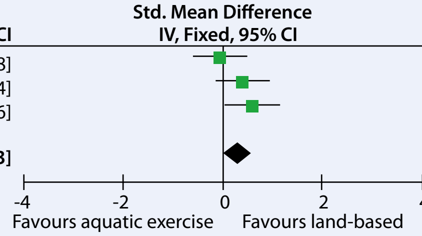
Aquatic exercise appears to have considerable short-term benefits compared with land-based exercise in patients with knee OA. Our data are consistent with findings from another systematic review of RCTs of aquatic exercise for hip or knee OA, which was performed to identify function, mobility, and other health outcomes [14].

There was moderate evidence of a moderate effect on physical function (SMD –0.55; 95% CI –0.94 to –0.16) in favor of aquatic exercise immediately after the intervention, when comparing aquatic exercise with nonexercise [36, 43]. This result is consistent with findings from a previous systematic review [16]. We conducted a fur-

Comparison 1. Physical function: aquatic exercise versus land-based exercise

	aquatic exercise			land-based exercise				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Yennan 2010	9.2	9.8	25	9.96	10.24	25	33.2%	-0.07 [-0.63, 0.48]
Wang 2011	-76	16	26	-82	14	26	33.9%	0.39 [-0.16, 0.94]
Lund 2008	-62.7	-62.3	27	-64.1	2.3	25	32.9%	0.60 [0.04, 1.16]
Total (95% CI)			**78**			**76**	**100.0%**	**0.31 [-0.01, 0.63]**

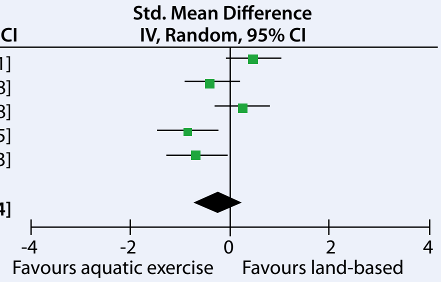
Heterogeneity: $Chi^2 = 2.97$, df = 2 (P = 0.23); $I^2 = 33\%$
Test for overall effect: Z =1.87 (P = 0.06)



Comparison 2. Pain: aquatic exercise versus land-based exercise

	aquatic exercise			land-based exercise				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Lund 2008	20.3	3.2	27	18.8	3.3	25	20.1%	0.45 [-0.10, 1.01]
Silva 2008	26.7	23.1	32	37.3	27.5	32	21.1%	-0.41 [-0.91, 0.08]
Wang 2011	-72	18	26	-76	15	26	20.2%	0.24 [-0.31, 0.78]
Wyatt 2001	2.4	1.6	23	3.8	1.6	23	19.1%	-0.86 [-1.47, -0.25]
Yennan 2010	0.7	0.53	25	1.41	1.3	25	19.7%	-0.70 [-1.28, -0.13]
Total (95% CI)			**133**			**131**	**100.0%**	**-0.25 [-0.74, 0.24]**

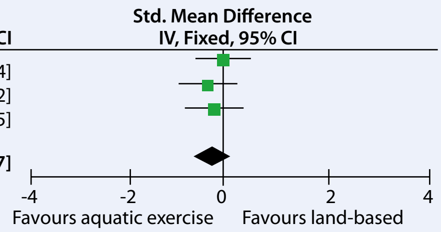
Heterogeneity: $Tau^2 = 0.24$; $Chi^2 = 16.04$, df = 4 (P = 0.003); $I^2 = 75\%$
Test for overall effect: Z = 0.99 (P = 0.32)



Comparison 3. Stiffness: aquatic exercise versus land-based exercise

	aquatic exercise			land-based exercise				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Wang 2011	-125	4.2	26	-125	6.1	26	35.3%	0.00 [-0.54, 0.54]
Wyatt 2001	-120.8	12	23	-117.3	14.2	23	30.9%	-0.26 [-0.84, 0.32]
Yennan 2010	1.24	1.27	25	1.56	1.71	25	33.7%	-0.21 [-0.77, 0.35]
Total (95% CI)			**74**			**74**	**100.0%**	**-0.15 [-0.47, 0.17]**

Heterogeneity: $Chi^2 = 0.48$, df = 2 (P = 0.79); $I^2 = 0\%$
Test for overall effect: Z =0.92 (P = 0.36)



Comparison 4. Quality of life: aquatic exercise versus land-based exercise

	aquatic exercise			land-based exercise				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Lund 2008	-43	2.4	27	-43.8	2.5	25	33.7%	0.32 [-0.23, 0.87]
Wang 2011	-73	12	26	-74	11	26	34.1%	0.09 [-0.46, 0.63]
Yennan 2010	-4.45	3.22	25	-5.76	3.36	25	32.2%	0.39 [-0.17, 0.95]
Total (95% CI)			**78**			**76**	**100.0%**	**0.26 [-0.05, 0.58]**

Heterogeneity: $Chi^2 = 0.66$, df = 2 (P = 0.72); $I^2 = 0\%$
Test for overall effect: Z =1.63 (P = 0.10)

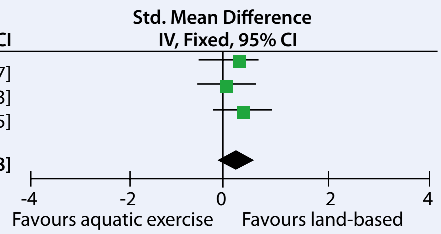


Fig. 4 ▲ Forest plot for effects of aquatic exercise on pain, physical function, quality of life, and stiffness

ther meta-analysis between land-based exercise and nonexercise and their effect on physical function, and determined there was no significant effect (◘ **Fig. 4**).

Based on these results, physicians may consider advising patients with knee OA to choose aquatic exercise to help maintain function.

When patients are unable to exercise on land, or find land-based exercise difficult, aquatic programs provide an enabling alternative strategy, especially in patients with greater disability. On the other hand, exercise on land may be arranged more easily and at a lower cost.

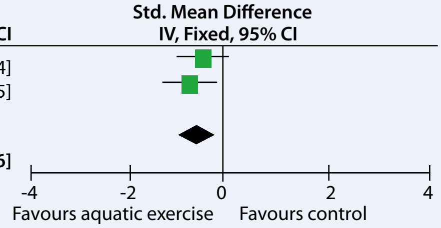
There was no evidence for stiffness, QOL, or mental health with aquatic exercise. The same observation was made for pain improvement with aquatic exercise immediately after the intervention when comparing aquatic exercise with nonexercise [36, 43]. This finding is different from two studies included in this review [11, 56], which reported aquatic exercise was better for pain reduction when compared with land-based exercise immediately after the interventions. The different pain measures used in these studies may partially explain the different results; a VAS was used to measure pain in the latter two studies. It is possible that the VAS was more sensitive to changes compared with the pain dimension of the KOOS or WOMAC. This may be seen in one study included in this review [43], which found no group differences in the pain dimension of the KOOS. Therefore, we suggest that future studies should use a VAS for pain measurement.

The effects on physical function did not last up to a 3-month follow-up according to the only study that reported such follow-up measurements [43]. There was limited evidence for pain improvement with aquatic exercise when comparing aquatic exercise with nonexercise. In addition, no evidence was found for physical function or QOL. Studies with long-term outcomes are necessary to determine further use of this therapy.

Comparison 5. Physical function: aquatic exercise versus nonexercise

Study or Subgroup	aquatic exercise Mean	SD	Total	nonexercise Mean	SD	Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Lund 2008	-76	16	26	-69	18	26	50.1%	-0.40 [-0.95, 0.14]
Wang 2011	-62.7	2.3	27	-61.1	2.2	27	49.9%	-0.70 [-1.25, -0.15]
Total (95% CI)			**53**			**53**	**100.0%**	**-0.55 [-0.94, -0.16]**

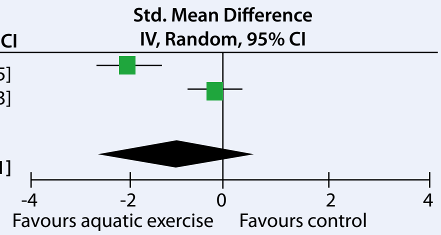
Heterogeneity: $Chi^2 = 0.56$, df = 1 (P = 0.46); $I^2 = 0\%$
Test for overall effect: Z = 2.78 (P = 0.005)



Comparison 6. Pain: aquatic exercise versus nonexercise

Study or Subgroup	aquatic exercise Mean	SD	Total	nonexercise Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Lund 2008	20.3	3.2	27	27.2	3.2	27	49.4%	-2.12 [-2.80, -1.45]
Wang 2011	-72	18	26	-68	18	26	50.6%	-0.22 [-0.76, -0.33]
Total (95% CI)			**53**			**53**	**100.0%**	**-1.16 [-3.03, 0.71]**

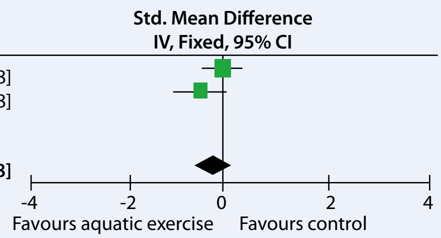
Heterogeneity: $Tau^2 = 1.72$; $Chi^2 = 18.48$, df = 1 (P < 0.0001); $I^2 = 95\%$
Test for overall effect: Z = 1.22 (P = 0.22)



Comparison 7. Quality of life: aquatic exercise versus nonexercise

Study or Subgroup	aquatic exercise Mean	SD	Total	nonexercise Mean	SD	Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Lund 2008	-43	2.4	27	-43.1	2.3	27	51.7%	0.04 [-0.49, 0.58]
Wang 2011	-73	12	26	-67	13	26	48.3%	-0.47 [-1.02, 0.08]
Total (95% CI)			**53**			**53**	**100.0%**	**-0.21 [-0.59, 0.18]**

Heterogeneity: $Chi^2 = 1.73$, df = 1 (P = 0.19); $I^2 = 42\%$
Test for overall effect: Z = 1.06 (P = 0.29)



Comparison 8. Physical function: land-based exercise versus nonexercise

Study or Subgroup	Land-based Mean	SD	Total	nonexercise Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Lund 2008	-64.1	2.3	25	-69	18	26	50.3%	0.37 [-0.18, 0.93]
Wang 2011	-82	14	26	-61.1	2.2	27	49.7%	-2.07 [-2.75, -1.40]
Total (95% CI)			**51**			**53**	**100.0%**	**-0.84 [-3.24, 1.55]**

Heterogeneity: $Tau^2 = 2.89$; $Chi^2 = 30.04$, df = 1 (P < 0.00001); $I^2 = 97\%$
Test for overall effect: Z = 0.69 (P = 0.49)

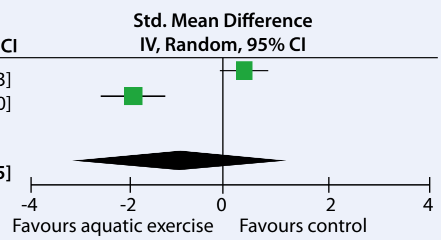


Fig. 4 ▲ Continued

There is a lack of information on patient satisfaction and adherence to the exercise intervention, despite the importance of patient engagement in exercise programs. One potential limitation of the present meta-analysis is the relatively small number of included studies, which makes it difficult to draw firm conclusions. A second limitation is the substantial heterogeneity and variety of exercise strategies among studies. A third limitation is whether the positive effects of aquatic exercise might only be temporary. We are unable to clarify this issue, since the longest follow-up was only 3 months and was reported in only one study [43].

Conclusion

Overall, aquatic and land-based exercises appear to result in comparable benefits for participants. Meta-analysis did not provide confidence that either aquatic or land-based exercise provides greater improvements in physical function, QOL, or pain. Variability in study parameters, study quality, and exercise strategies may have confounded perception of the effects. Meanwhile, aquatic exercise has some short-term benefits compared with nonexercise. Studies in this area are still too few to provide further recommendations on how to apply this therapy. More research is required to determine if the positive effects of aquatic exercise can be supported by appropriately designed studies with medium- and long-term follow-ups.

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Compliance with ethical guidelines

Conflict of interest. Meili Lu, Youxin Su, Yingjie Zhang, Ziyi Zhang, Wenting Wang, Zhen He, Feiwen Liu, Yanan Li, Changyan Liu, Yiru Wang, Lu Sheng, Zhengxuan Zhan, Xu Wang, and Naixi Zheng state that there are no conflicts of interest.

The accompanying manuscript does not include studies on humans or animals.

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