Systematic Review and Meta-Analysis

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Is aquatic exercise more effective than land-based exercise for knee osteoarthritis?

Rui Dong, MD[a,b], Yunyao Wu, MD[c], Shibing Xu, MD[d], Lei Zhang, MD[e], Jun Ying, MD[a,b], Hongting Jin, MD[a,b], Pinger Wang, MD[a,b], Luwei Xiao, MD[a,b], Peijian Tong, MD[a,b,f,*]

Abstract

Background: This study aimed to systemically review the effectiveness of aquatic exercise (AQE) compared to land-based exercise (LBE) in treating knee osteoarthritis (OA).

Methods: The Medline, Embase, Web of Science, Cochrane Central Register of Controlled Clinical Trials, CINAHL, and psycINFO databases were comprehensively searched for randomized controlled trials (RCTs) evaluating the effectiveness of AQE and LBE for knee OA from their inception date to September 24, 2018. The risk of bias was examined using the Cochrane Collaboration Tool, and Review Manager 5.3 was used for data collation and analysis.

Results: Eight RCTs were included, involving a total of 579 patients. The meta-analysis showed that there was no significant difference between AQE and LBE for pain relief, physical function, and improvement in the quality of life, for both short- and long-term interventions, in patients with knee OA. However, the adherence and satisfaction level for AQE was higher than for LBE. Compared to no intervention, AQE showed a mild effect for elevating activities of daily living (standardized mean difference [SMD]: −0.55, 95% confidence interval [CI] [−0.94, −0.16], $P=.005$) and a high effect for improving sports and recreational activities (SMD: −1.03, 95% CI [−1.82, −0.25], $P=.01$).

Conclusion: AQE is comparable to LBE for treating knee OA.

Abbreviations: ADL = activities of daily living, AQE = aquatic exercise, CI = confidence interval, KOOS = knee injury and osteoarthritis outcome score, LBE = land-based exercise, OA = osteoarthritis, QOL = quality of life, RCT = randomized controlled trials, SF-36 = the medical outcomes study item short from health survey, SMD = standardized mean difference, sport&rec = sports and recreational activities, VAS = visual analog scale, WOMAC = the Western Ontario and McMaster Universities Osteoarthritis Index.

Keywords: aquatic exercise, knee osteoarthritis, land-based exercise, meta-analysis

1. Introduction

Osteoarthritis (OA) is a common joint disorder which frequently affects the knee joint, especially in middle aged and elderly people. Recently, a Chinese population-based observation study estimated that the prevalence of symptomatic knee OA was nearly 8.1%.[1] With an increasing aged population in China, the prevalence of knee OA is still rising rapidly. Clinically, patients with knee OA usually present with radiographic narrowing of the joint space accompanied by articular degradation, subchondral bone sclerosis, and osteophyte formation. These result in chronic knee joint pain, stiffness, and physical disability.[2] This chronic and disabling condition not only diminishes an individual's quality of life (QOL), but it also enhances anxiety, fear, and even depression.[3] To date, the signs and symptoms of knee OA can only be alleviated with a joint replacement.[4]

Land-based exercise (LBE), as a nonpharmacologic intervention, is highly recommended for the treatment of knee OA, since it can improve muscle strength, relieve pain, reduce stiffness, and ameliorate physical function.[5–7] Exercise is a broad concept that encompasses many forms including resistance, isokinetic, and aerobic exercise. All types of exercise could significantly relieve knee OA joint pain and improve physical function.[8–11] A Cochrane systematic review further testified that LBE provides short-term pain control and improves physical function which is sustained for at least 2 to 6 months after the exercise intervention in patients with knee OA.[12] Despite the importance of LBE, excessive exercise dosage may worsen arthritis symptoms by increasing weight-bearing or load.[4] Statistical analysis indicated that arthritic patients present a lower level of physical activity compared to the general population,[13] and nearly 50% of OA individuals were reluctant to do extra exercise due to pain.[4,14] Even if they participated in a physical exercise program, long-term adherence is problematic. Therefore, it is important to explore other treatment options for patients with knee OA.

Editor: Anis Jellad.

RD and YW contributed equally to this work.

This study was supported by the National Natural Science Foundation of China (no: 81774332, 81774346, 81873324, and 81873325).

The authors have no funding and conflicts of interest to disclose.

Supplemental Digital Content is available for this article.

[a] The First Clinical Medical College of Zhejiang Chinese Medical University, [b] Institute of Orthopaedic and Traumatology, Zhejiang Province, Hangzhou, Zhejiang, [c] The Affiliated Hospital of Jiangxi University of Traditional Chinese Medicine, Nanchang, Jiangxi, [d] The First People's Hospital of Xiaoshan, [e] Xiaoshan Traditional Chinese Medical Hospital, [f] Department of Orthopaedic Surgery, The First Affiliated Hospital of Zhejiang Chinese Medical University, Hangzhou, Zhejiang, China.

[*] Correspondence: Peijian Tong, Department of Orthopaedic Surgery, The First Affiliated Hospital of Zhejiang Chinese Medical University, Zhejiang 310006, China (e-mail: tongpeijian@163.com).

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Medicine (2018) 97:52(e13823)

Received: 4 July 2018 / Received in final form: 19 November 2018 / Accepted: 1 December 2018

http://dx.doi.org/10.1097/MD.0000000000013823

Aquatic exercise (AQE) or hydrotherapy refers to exercise performed in the water, and it has been used in the treatment of diseases for more than 18 years.[15] It has many advantages compared to LBE. Firstly, the relatively constant water temperature and hydrostatic pressure may facilitate blood circulation, ease soft-tissue contracture, and relieve muscle spasms and fatigue. Secondly, since water resistance acts in the opposite direction to body motion, greater muscle activity is required which may enhance muscular strengthening. Thirdly, water buoyancy can reduce the likelihood of injury, and protect against joint degradation by reducing weight bearing.[16–18] In addition, AQE provides a more comfortable and suitable environment for patients with knee OA who are reluctant to exercise.[19] Therefore, AQE may be a beneficial treatment for knee OA. Studies that have examined the effectiveness of AQE for treating OA have suggested that AQE can relieve joint pain, and improve physical function and QOL.[14,19]

Although there are many advantages of AQE compared to LBE, it is still unclear which is more effective in treating knee OA. Many studies have compared the effectiveness of AQE and LBE; however, consistent conclusions have not been drawn. It is therefore necessary to determine which type of exercise is more efficient. In this study, a systematic review and meta-analysis of randomized controlled trials (RCTs) was conducted to compare AQE and LBE nonpharmacologic treatments for knee OA. Pain relief, symptoms, physical function, and improvement in the QOL were assessed, with the aim of determining the most effective type of exercise for knee OA management.

2. Materials and methods

This research is reported according to the PRISMA statement guidelines.[20] No ethical approval is required as the research is based on previously published articles.

2.1. Search strategy

Six databases, including Medline (via PubMed), Embase, Web of Science, Cochrane Central Register of Controlled Clinical Trials, CINAHL, and psyclNFO, were searched from their inception date to September 24, 2018. The search strategy was based on combinations of medical subject headings and keywords. The Medline search strategy is described in the supplementary material (Table S1, http://links.lww.com/MD/C723). Strategies for the other databases were adjusted to meet the requirements of each database. In addition, to achieve a full-scale search, the references of relevant articles were searched. The systematic review details were registered in PROSPERO: the International prospective register of systematic reviews (no: CRD42018095026).

2.2. Study selection

All included studies met the following inclusion criteria: the study design was a RCT; patients were diagnosed with knee OA according to symptoms and radiologic findings without any invasive intervention; The RCT compared AQE to LBE. All types of exercise developed in a therapeutic/heated indoor/outdoor pool were eligible; and the experimental group which received AQE combined with the certain therapy (e.g., nonsteroidal anti-inflammatory drugs) and the control group with the same certain therapy were also included.

Studies were excluded if they met the following criteria: the study included animal experiments, and it was a review, cross-over study, cohort study, PICO protocol, or conference abstract; the study included an AQE experimental group, but the control group did not perform any exercise (e.g., no intervention or just education) and there was no LBE group; the study focused not only on knee OA, but other joint diseases as well (e.g., hip OA), precluding the ability to separate the outcomes from the patients with knee OA; the study had been published previously; and the study was not published in the English language.

2.3. Data extraction

Two authors (RD and YW) independently extracted data from each study using a predefined data extraction form which included: the first author's name, the year of publication, the patient characteristics, methodologic features of the studies, research country, intervention and duration, follow-up period, main outcome measurements, withdraw, and quality of trial design. Email was used to contact the original authors when the above information could not be obtained from the full-text of the included studies. Uncertainty or disagreement was resolved by discussion or consensus with a 3rd author (PT).

2.4. Quality assessment and bias analysis

The quality of all of the studies which met the inclusion criteria was assessed using the Modified Jadad score.[21] It contains four main sections examining almost all of the important elements of RCTs. It is a 7-point system with a score $\geq$4 considered as high quality, and a score $<$3 deemed as low quality. The bias of each study was evaluated using the Cochrane Handbook for Systematic Reviews of Interventions.[22] It mainly assesses selection bias, performance bias, detection bias, attrition bias, reporting bias, and other biases. The bias of each domain was defined as low risk, unclear risk, or high risk. Two authors (RD and YW), independently assessed the quality and the bias of the included research studies, and disagreement was resolved by discussion or consensus with a 3rd author (PT).

2.5. Outcome measurement

The main outcomes that were examined included: pain relief, physical function, and symptom and QOL improvement. Across the studies, pain relief was measured using the visual analog scale [23](VAS), the Western Ontario and McMaster Universities Osteoarthritis Index[24] (WOMAC) pain score, and the knee injury and OA outcome score[24] (KOOS). Symptoms were measured using the KOOS for symptoms, physical function was measured using the medical outcomes study 36-item short form health survey (SF-36),[25] the KOOS for activities of daily living (ADL), and sports and recreational activities (sport&rec). QOL was measured using the KOOS for QOL.

2.6. Statistical analysis

Review Manager (RevMan) software (Computer program, version 5.3, Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014) was used for data analysis. All continuous outcomes were presented as the standardized mean difference (SMD) with 95% confidence intervals (CIs). Heterogeneity was defined using the P-value and I^2 from the standard Chi-squared test. A fixed-effect model was performed when the relevant data showed low heterogeneity ($P>.1$, $I^2<50\%$); otherwise, a random-effect model was conducted.[26] The differences between groups were considered as significant when the 95% CI did not include zero. Effect size was defined as small (SMD > 0.2), moderate (SMD > 0.5), or large (SMD > 0.8).

3. Results

3.1. Study selection and study characteristics

A total of 1264 studies were identified from the 6 databases. After removing duplicates and reviewing the titles and abstracts of 755 records, the full text of 45 records was reviewed. Finally, 8 RCTs with 579 participants were included in the meta-analysis (Fig. 1).

The characteristics of each study are summarized and presented in Table 1. All of the studies were published in English between 2001 and 2018, and they were conducted in Brazil,[16,27] China,[28] Finland,[29] Denmark,[30] Korea,[31] Thailand,[32] and the United States.[33] Patients who participated in these studies were diagnosed with knee OA according to the American College of Rheumatology criteria,[16,27,30] or the Kellgren–Lawrence radiographic criteria for defining the disease stage.[27,29,31] Other studies which diagnosed knee OA according to symptoms and radiographic findings did not specify the exact diagnostic criteria.[28,32,33] There were no significant differences between the AQE and LBE groups at baseline for all of the included studies. Gender distribution, which is essential for knee OA research, was described in most of the included records.[16,27–31] Each research design included a LBE group as a positive control; moreover, 3 of them involved a negative control group with no intervention[28,30] or home-based exercise.[31]

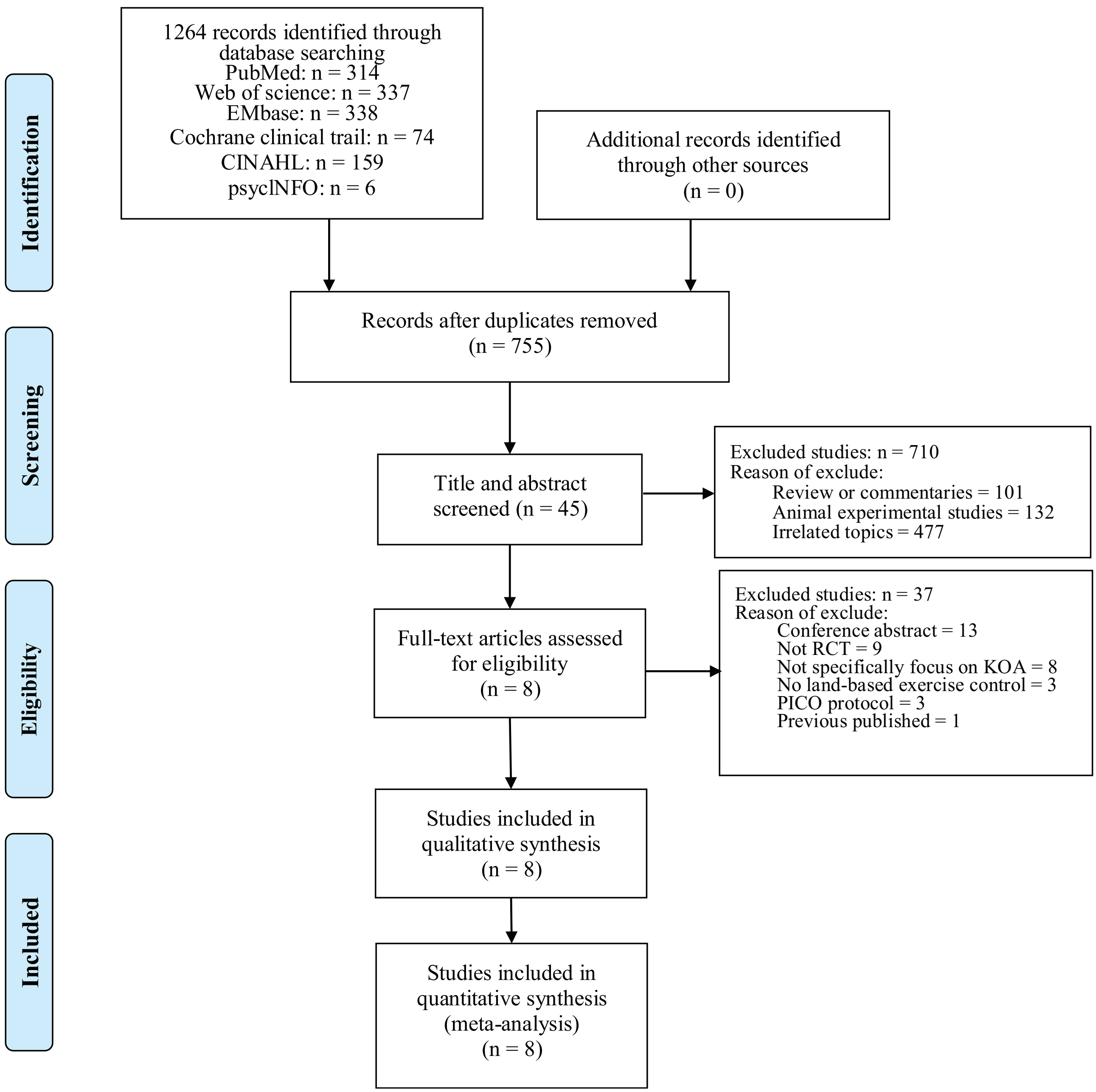


Figure 1. The flowchart of literature selection procedure.

Table 1

Characteristic of the included studies.

Study	Country	Patient no	Gender (female)	Age, yr	BMI, kg/m^2	Diagnostic	Disease stage KL	Intervention	Treatment period	Outcome assessment
Taglietti et al, 2018	Brazil	LBE: 29	62.1%	68.7 ± 6.7	30.4 ± 0.9	Knee OA according to the American College of Rheumatology	I-II: 58%	1. Health education and home knee osteoarthritis exercise	8W intervention	VAS, WOMAC pain, SF-36
		AQE:31	74.2%	67.3 ± 5.9	29.2 ± 0.8	Kellgren–Lawrence radiographic criteria	III-VI: 42%	2. Aquatic exercise	3M follow-up after intervention	
Waller et al, 2017	Finland	LBE:44	100%	63.9 ± 2.4	27.1 ± 3.5	Kellgren–Lawrence radiographic criteria	I: 54.02%	1. Normal physical activity and stretching, relaxation exercise	16W intervention	KOOS pain, symptoms, ADL, sport&Rec, QOL
		AQE:43	100%	63.8 ± 2.4	26.6 ± 3.8		II:45.98%	2. Intensive aquatic resistance training	12M follow-up after intervention	
Wang et al, 2011	China	NI:26	84.6%	67.9 ± 5.9	26.6 ± 2.08	Medical diagnosis (symptoms and radiographic)	N/A	1. No intervention	12W intervention	KOOS pain, symptoms, ADL, sport&Rec, QOL
		LBE:26	88.5%	68.3 ± 6.4	25.4 ± 2.4			2. Land-based exercise		
		AQE:26	84.6%	66.7 ± 5.6	26.6 ± 2.5			3. Aquatic exercise		
Yennan et al, 2010	Thailand	LBE:25	N/A	66.4 ± 4.4	23.7 ± 2.2	Medical diagnosis (historic, symptoms and radiographic)	N/A	1. Land-based exercise	6W intervention	VAS, WOMAC pain, stiffness, physical function, KOOS pain, symptoms, ADL, sport&Rec, QOL
		AQE:25	N/A	65.6 ± 4.9	24.4 ± 2.7			2. Aquatic exercise		
Lim et al, 2010	Korea	HBE:20	87.5%	67.8 ± 6.5	27.7 ± 2.0	Kellgren–Lawrence radiographic criteria	N/A	1. Home-based exercise	8W intervention	WOMAC total, SF-36
		LBE:22 AQE:24	84%	66.4 ± 6.0	27.6 ± 1.7			2. Land-based exercise		
			88.5%	66.8 ± 5.7	27.9 ± 1.5			3. Aquatic exercise		
Silva et al, 2008	Brazil	LBE:32 AQE:32	90.66%	59 ± 6.08	N/A	Knee OA according to the American College of Rheumatology.	N/A	1. land-based exercise	18W intervention	VAS, WOMAC total
			93.75%	59 ± 7.60				2. Water-based exercise		
Lund et al, 2008	Denmark	NI:27	66%	70 ± 9.9	N//A	Knee OA according to the American College of Rheumatology.	N/A	1. no intervention	8W intervention	VAS, KOOS pain, symptoms, ADL, sport&Rec, QOL
		LBE:25	88%	68 ± 9.5				2. Land-based exercise	3M follow-up after intervention	
		AQE:27	83%	65 ± 12.6				3. Aquatic exercise		
Wyatt et al, 2001	USA	LBE:21	N/A	45-70	N/A	Medical diagnosis (symptoms and radiographic)	N/A	1. land-based exercise	6W intervention	VAS
		AQE:21						2. Water-based exercise		

ADL = activities of daily living, AQE = aquatic exercise group, HBE = home-based exercise group, KOOS = Knee injury and Osteoarthritis Outcome Score, LBE = land-based exercise group, NI = no intervention group, NR = no reported, QOL = quality of life, SF-36 = the medical outcomes study item short from health survey, sport&rec = sports and recreational activities, VAS = visual analog scale, WOMAC = The Western Ontario and McMaster Universities Osteoarthritis Index.

Table 2

The prescription of AQE in each study.

Study	Aquatic exercise duration, min	Procedure (duration)	Water temperature, °C	Water depth (M)	Frequency (times per wk)
Taglietti et al, 2018	60	Warm up (5 min) Isometric and dynamic exercises (15 min) Aerobic exercises (20 min) Step training and proprioceptive exercises (10 min) Massage and relaxation (10 min)	32	1.2	2
Waller et al, 2017	60	Warm up (15 min) Resistance exercises and isokinetic exercises (30 min) Cool down (15 min)	30-32	N/A	3
Wang et al, 2011	50	Warm up (5 min) Flexibility training (10 min) Aerobic training (10 min) Lower body training (10 min) Upper body training (10 min) Cool down (5 min)	30	N/A	3
Yennan et al 2010	65	Warm up (10 min) Exercise (double-leg squat, double-leg calf raises stand stretch and bend knee, standing kick leg-to-side, standing kick leg-to-front, sitting stretch knee, sit spin bike, and fast walking forward and backward) (45 min) Cool down (10 min)	Ambient temperature	Waist height	3
Lim et al, 2010	40	Warm up (5 min) Strength training, resistive exercises, aerobic training (30 min) Cool down (5 min)	34	1.15	3
Silva et al, 2008	50	Stretching exercise (N/A) Isometric strengthening (N/A) Isotonic strengthening (N/A) Gait training (N/A)	32	1.2	3
Lund et al, 2008	50	Warm up (10 min) Resistance exercises (20 min) Balance and stabilizing exercises (10 min) Lower limb stretches training (5 min) Cool-down (5 min)	33.5	N/A	2
Wyatt et al, 2001	N/A	2 sets of manual resistance knee extension and knee flexion (N/A) 4-way straight leg raises, mini-squats (N/A) walking forward (N/A)	32	1.5	3

NR = no reported.

The exercise program for the AQE group in each study is summarized in Table 2. AQE was performed for 40 to 65 minutes, 2 to 3 times a week, for 6,[32,33] 8,[27,30,31] 12,[28] 16,[29] or 18[16] weeks. Water depth was 1.15 to 1.5 m and water temperature was 30°C to 34°C. The baseline outcome measurements for all of the included studies are presented in the supplementary material (Table S2, http://links.lww.com/MD/C723) (Table 3).

3.2. Risk of bias assessment

The risk of bias assessment is presented in Figure 2. Selection bias existed in most trials, and although these trials reported randomization, only 6 of the included records described the randomization method. These studies used random sequence generation,[27,28] block randomization,[29–31] and drawing lots[16]; the other trials did not specify the exact randomization method.[32,33] Two records[27,30] reported using opaque enve-

Table 3

Modified Jadad score for each literature.

Study	Randomized	Randomization concealment	Blinded	Withdrawal	Total Jadad score
Taglietti et al, 2018	2	2	0	1	5
Waller et al, 2017	2	1	0	1	4
Wang et al, 2011	2	1	0	1	4
Yennan et al, 2010	1	0	0	0	1
Lim et al, 2010	2	1	0	1	4
Silva et al, 2008	2	1	0	0	3
Lund et al, 2008	2	1	0	1	4
Wyatt et al, 2001	1	2	0	1	4

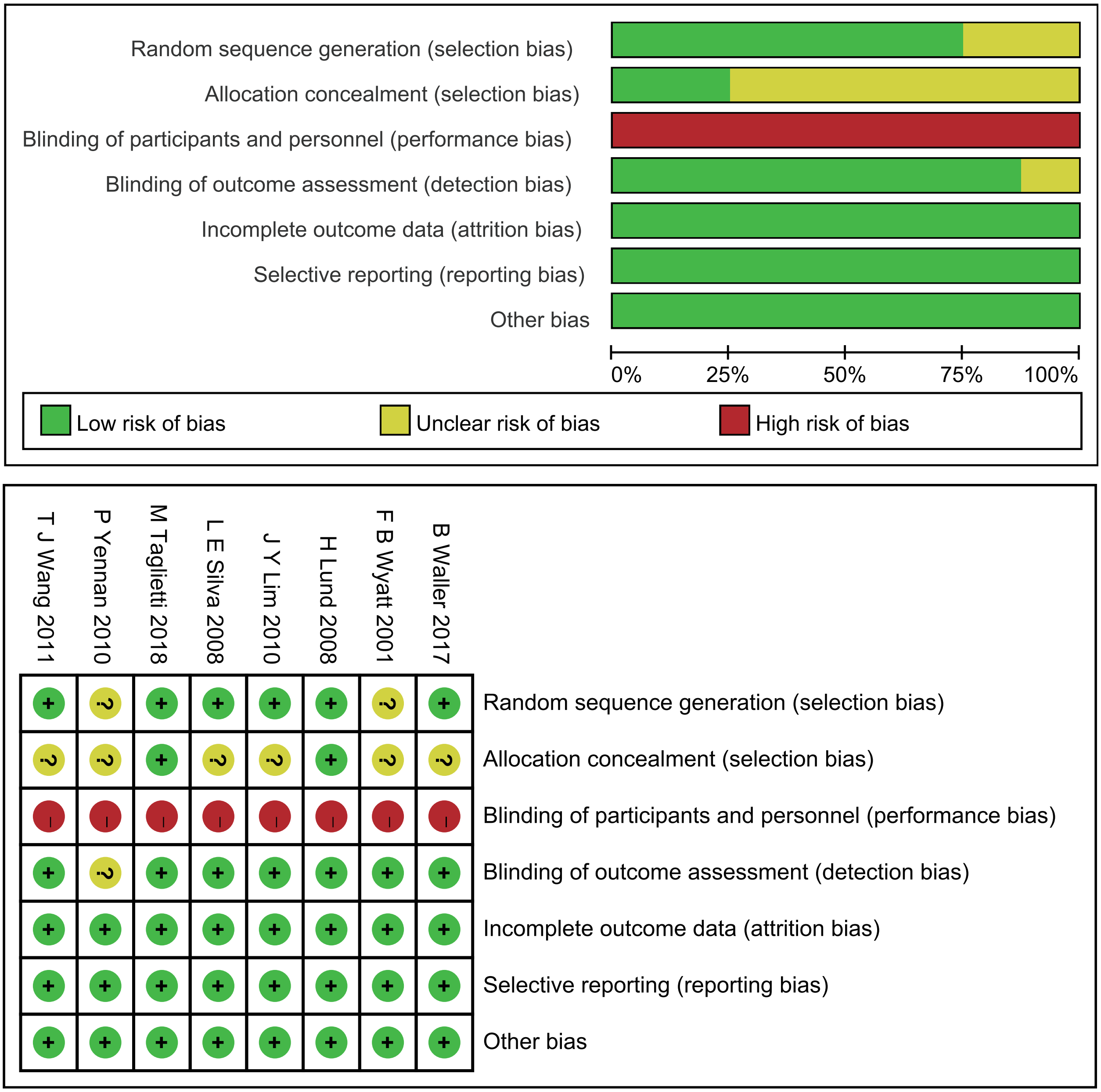


Figure 2. (A) Risk of bias graph. (B) Risk of bias summary.

lopes to conceal group allocation; this was not detailed in any of the other studies. All studies had a high risk of performance bias due to the nature of the interventions. Most trials reported that a blinded investigator performed the outcome measurements, and only 1 study[32] had detection bias. There were no other biases across the included trials.

3.3. Effect of intervention

3.3.1. Pain control. Since joint pain is the primary symptom described by patients with knee OA, all of the included studies assessed pain as the primary outcome. VAS score,[16,27,30,32,33] WOMAC pain,[27,32] and KOOS pain[28,29,32,33] were used to measure pain. Studies which used VAS and WOMAC pain showed high heterogeneity (VAS: $P<.001$, $I^2=85\%$, WOMAC pain: $P<.001$, $I^2=98\%$), whereas KOOS pain showed moderate heterogeneity ($P=.20$, $I^2=36\%$). There were no significant differences in VAS (SMD: −0.62, 95% CI [−1.27, 0.03], $P=.06$), WOMAC pain (SMD: −1.66, 95% CI [−4.90, 1.58], $P=.31$), and KOOS pain (SMD: 0.19, 95% CI [−0.07, 0.45], $P=.15$) in the AQE group compared to the LBE group (Fig. 3).

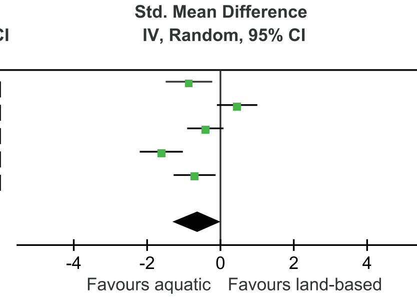
3.3.2. Symptoms. Three records assessed symptoms using KOOS symptom.[28,29,33] A random effects model was used for data analysis due to the high degree of heterogeneity ($P=.009$, $I^2=74\%$). The meta-analysis (SMD: 0.19, 95% CI [−0.32, 0.71], $P=.46$) showed that there was no significant difference between the AQE and LBE groups for symptom improvement (Fig. 4).

3.3.3. Physical function improvement. Physical function was measured using KOOS ADL,[28–30,32] KOOS sport&rec,[28–30,32] and SF-36 physical function.[27,31] Heterogeneity was not

Comparison 1. VAS : aquatic exercise versus land-based exercise

Study or Subgroup	land-based exercise Mean	SD	Total (n)	aquatic exercise Mean	SD	Total (n)	Weight	Std. Mean Difference IV, Random, 95% CI
F B Wyatt 2001	-3.8	1.6	21	-2.4	1.6	21	19.3%	-0.86 [-1.49, -0.22]
H Lund 2008	-18.8	3.3	25	-20.3	3.2	27	20.2%	0.45 [-0.10, 1.01]
L E Silva 2008	-37.3	27.5	32	-26.7	23.1	32	20.8%	-0.41 [-0.91, 0.08]
M Taglietti 2018	-3.8	0.6	29	-2.9	0.5	31	19.8%	-1.61 [-2.20, -1.03]
P Yennan 2010	-1.41	1.3	25	-0.7	0.53	25	20.0%	-0.70 [-1.28, -0.13]
Total (95% CI)			**132**			**136**	**100.0%**	**-0.62 [-1.27, 0.03]**

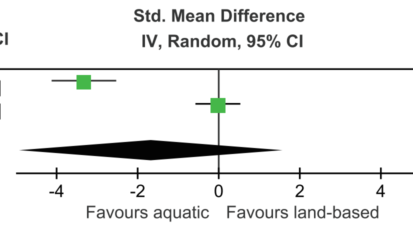
Heterogeneity: Tau² = 0.47; Chi² = 26.75, df = 4 (P < 0.0001); I² = 85%
Test for overall effect: Z = 1.86 (P = 0.06)



Comparison 2. WOMAC pain : aquatic exercise versus land-based exercise

Study or Subgroup	land-based exercise Mean	SD	Total (n)	aquatic exercise Mean	SD	Total (n)	Weight	Std. Mean Difference IV, Random, 95% CI
M Taglietti 2018	-8.1	1.5	29	-4.2	0.7	31	49.6%	-3.33 [-4.12, -2.53]
P Yennan 2010	-3.12	3.87	25	-3.04	3.68	25	50.4%	-0.02 [-0.58, 0.53]
Total (95% CI)			**54**			**56**	**100.0%**	**-1.66 [-4.90, 1.58]**

Heterogeneity: Tau² = 5.34; Chi² = 44.51, df = 1 (P < 0.00001); I² = 98%
Test for overall effect: Z = 1.00 (P = 0.31)



Comparison 3. KOOS pain : aquatic exercise versus land-based exercise

Study or Subgroup	land-based exercise Mean	SD	Total (n)	aquatic exercise Mean	SD	Total (n)	Weight	Std. Mean Difference IV, Fixed, 95% CI
B Waller 2017	83.3	11.7	43	84.3	10.5	44	37.7%	-0.09 [-0.51, 0.33]
H Lund 2008	62	2.5	26	60.2	2.4	20	18.3%	0.72 [0.12, 1.32]
P Yennan 2010	5.04	5.18	25	4.16	4.08	25	21.6%	0.19 [-0.37, 0.74]
T J Wang 2011	76	15	26	72	18	26	22.4%	0.24 [-0.31, 0.78]
Total (95% CI)			**120**			**115**	**100.0%**	**0.19 [-0.07, 0.45]**

Heterogeneity: Chi² = 4.69, df = 3 (P = 0.20); I² = 36%
Test for overall effect: Z = 1.46 (P = 0.15)

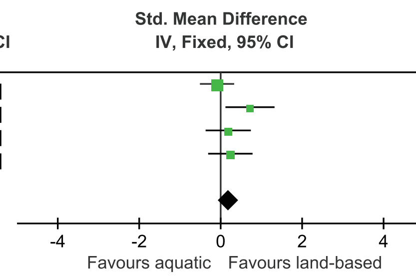


Figure 3. Forest plot of aquatic exercise (AQE) vs land-based exercise (LBE) interventions in pain.

apparent for KOOS ADL ($P=.16$, $I^2=41\%$); however, KOOS sport&rec and SF-36 physical function demonstrated high heterogeneity (KOOS sport&rec: $P=.04$, $I^2=64\%$, SF-36 physical function: $P<.001$, $I^2=98\%$). There were no significant differences in KOOS ADL (SMD: 0.17, 95% CI [−0.08, 0.43], $P=.19$), KOOS sport&rec (SMD: 0.24, 95% CI [−0.19, 0.67], $P=.27$), or SF-36 physical function (SMD: −1.68, 95% CI [−5.38, 2.03], $P=.38$) between the AQE and LBE groups. Therefore, the meta-analysis revealed that there was no difference in the improvement of physical function between the 2 interventions (Fig. 5).

3.3.4. Quality of life. Four studies assessed QOL using KOOS QOL.[28–30,32] Heterogeneity was not observed in the analyses for QOL ($P=.80$, $I^2=0\%$), and the meta-analysis (SMD: 0.19, 95% CI [−0.07, 0.44], $P=.15$) demonstrated that there was no significant difference in the improvement of QOL between the 2 groups (Fig. 6).

Comparsion 1. KOOS symptom : aquatic exercise versus land-based exercise

Study or Subgroup	land-based exercise Mean	SD	Total (n)	aquatic exercise Mean	SD	Total (n)	Weight	Std. Mean Difference IV, Random, 95% CI
B Waller 2017	77.5	14.9	44	80.9	12.1	43	27.6%	-0.25 [-0.67, 0.17]
H Lund 2008	66.9	2.3	25	64.6	2.31	27	23.7%	0.98 [0.40, 1.56]
P Yennan 2010	3.64	3.48	25	3.6	3.63	25	24.3%	0.01 [-0.54, 0.57]
T J Wang 2011	71	16	26	69	20	26	24.5%	0.11 [-0.44, 0.65]
Total (95% CI)			**120**			**121**	**100.0%**	**0.19 [-0.32, 0.71]**

Heterogeneity: Tau² = 0.20; Chi² = 11.61, df = 3 (P = 0.009); I² = 74%
Test for overall effect: Z = 0.74 (P = 0.46)

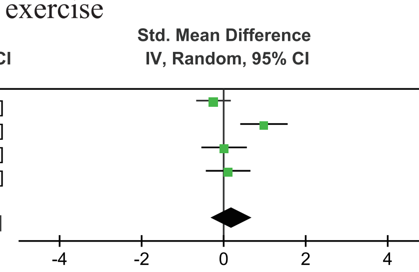
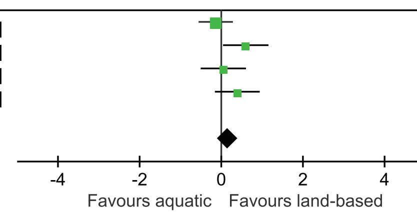


Figure 4. Forest plot of aquatic exercise (AQE) vs land-based exercise (LBE) interventions in symptom.

Comparsion 1. KOOS ADL : aquatic exercise versus land-based exercise

Study or Subgroup	land-based exercise Mean	SD	Total (n)	aquatic exercise Mean	SD	Total (n)	Weight	Std. Mean Difference IV, Fixed, 95% CI
B Waller 2017	86	14.6	44	87.7	9.7	43	36.6%	-0.14 [-0.56, 0.29]
H Lund 2008	64.1	2.3	25	62.7	2.3	27	20.9%	0.60 [0.04, 1.16]
P Yennan 2010	9.4	10.11	25	8.88	10.08	25	21.1%	0.05 [-0.50, 0.61]
T J Wang 2011	82	14	26	76	16	26	21.5%	0.39 [-0.16, 0.94]
Total (95% CI)			**120**			**121**	**100.0%**	**0.17 [-0.08, 0.43]**

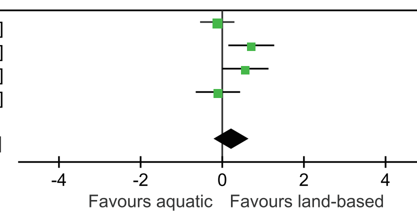
Heterogeneity: Chi² = 5.12, df = 3 (P = 0.16); I² = 41%
Test for overall effect: Z = 1.31 (P = 0.19)



Comparsion 2. KOOS sport&rec : aquatic exercise versus land-based exercise

Study or Subgroup	land-based exercise Mean	SD	Total (n)	aquatic exercise Mean	SD	Total (n)	Weight	Std. Mean Difference IV, Random, 95% CI
B Waller 2017	67.6	26.5	44	70.6	21.7	43	28.7%	-0.12 [-0.54, 0.30]
H Lund 2008	28.4	3.1	25	26.2	3	27	23.6%	0.71 [0.15, 1.27]
P Yennan 2010	7.64	5.85	25	4.72	4.15	25	23.5%	0.57 [0.00, 1.13]
T J Wang 2011	68	17	26	70	20	26	24.2%	-0.11 [-0.65, 0.44]
Total (95% CI)			**120**			**121**	**100.0%**	**0.24 [-0.19, 0.67]**

Heterogeneity: Tau² = 0.12; Chi² = 8.25, df = 3 (P = 0.04); I² = 64%
Test for overall effect: Z = 1.09 (P = 0.27)



Comparsion 3. SF-36 physical function : aquatic exercise versus land-based exercise

Study or Subgroup	land-based exercise Mean	SD	Total (n)	aquatic exercise Mean	SD	Total (n)	Weight	Std. Mean Difference IV, Random, 95% CI
J Y Lim 2010	40.4	7.9	22	38.8	7.7	24	50.3%	0.20 [-0.38, 0.78]
M Taglietti 2018	61.5	4.1	29	74.3	2.9	31	49.7%	-3.58 [-4.41, -2.74]
Total (95% CI)			**51**			**55**	**100.0%**	**-1.68 [-5.38, 2.03]**

Heterogeneity: Tau² = 7.01; Chi² = 53.21, df = 1 (P < 0.00001); I² = 98%
Test for overall effect: Z = 0.89 (P = 0.38)

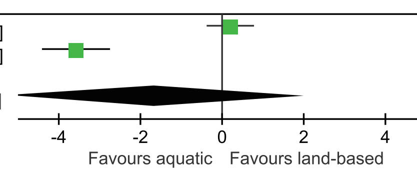


Figure 5. Forest plot of aquatic exercise (AQE) vs land-based exercise (LBE) interventions in physical function.

3.3.5. AQE compared to no intervention. Two studies[28,30] included 3 groups (AQE, LBE, and no intervention), so a meta-analysis was conducted to compare the AQE group to the no intervention group. KOOS pain ($P=.50$, $I^2=0\%$), KOOS ADL ($P=.46$, $I^2=0\%$), and KOOS QOL ($P=.19$, $I^2=42\%$) presented negligible heterogeneity. KOOS symptom ($P=.02$, $I^2=81\%$) and KOOS sport&rec ($P=.006$, $I^2=72\%$) demonstrated high heterogeneity. The results showed a significant improvement in KOOS ADL (SMD: −0.55 95% CI [−0.94, −0.16], $P=.005$) and sport&rec (SMD: −1.03, 95% CI [−1.82, −0.25], $P=.01$) in the AQE group compared to the no intervention group, but no significant differences were observed for KOOS pain (SMD: −0.09, 95% CI [−0.47, 0.30], $P=.66$), symptom (SMD: −0.89, 95% CI [−1.81, 0.04], $P=.06$), or QOL (SMD: −0.21, 95% CI [−0.59, 0.18], $P=.29$) (Fig. 7).

3.3.6. Outcome follow-up. Three trials reported follow-up durations of 3 months[27,30] and 12 months[29] after the intervention, which can be considered to be relatively long-term follow-up periods for the study outcomes. Pain, physical function, and QOL improvement was measured using VAS[16,27,30] and KOOS.[29,30] We observed high heterogeneity in VAS ($P<.001$, $I^2=97\%$) and KOOS sport&rec ($P<.001$, $I^2=94\%$). Heterogeneity was not observed for KOOS pain ($P=1.0$, $I^2=0\%$), symptom ($P=.78$, $I^2=0\%$), ADL ($P=.50$, $I^2=0\%$) or QOL ($P=.29$, $I^2=11\%$). No statistically significant effects were evident for VAS (SMD: −0.25, 95% CI [−2.57, 2.06],

Comparsion 1. KOOS Qol : aquatic exercise versus land-based exercise

Study or Subgroup	land-based exercise Mean	SD	Total (n)	aquatic exercise Mean	SD	Total (n)	Weight	Std. Mean Difference IV, Fixed, 95% CI
B Waller 2017	74.1	23.1	44	72.6	18.1	43	36.3%	0.07 [-0.35, 0.49]
H Lund 2008	43.8	2.5	25	43	2.4	27	21.4%	0.32 [-0.23, 0.87]
P Yennan 2010	5.76	3.36	25	4.56	3.22	25	20.5%	0.36 [-0.20, 0.92]
T J Wang 2011	74	11	26	73	12	26	21.7%	0.09 [-0.46, 0.63]
Total (95% CI)			**120**			**121**	**100.0%**	**0.19 [-0.07, 0.44]**

Heterogeneity: Chi² = 1.02, df = 3 (P = 0.80); I² = 0%
Test for overall effect: Z = 1.45 (P = 0.15)

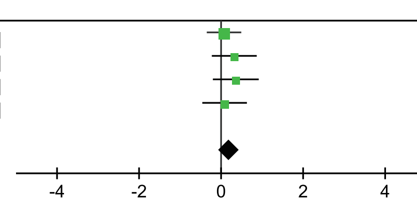


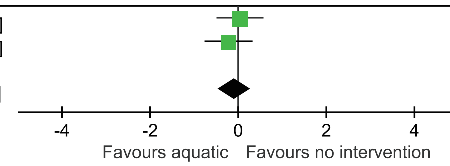
Figure 6. Forest plot of aquatic exercise (AQE) vs land-based exercise (LBE) interventions in quality of life.

Comparsion 1. KOOS pain : aquatic exercise versus no intervention

Study or Subgroup	no intervention Mean	SD	Total (n)	aquatic exercise Mean	SD	Total (n)	Weight	Std. Mean Difference IV, Fixed, 95% CI
H Lund 2008	60.3	2.4	27	60.2	2.4	27	51.1%	0.04 [-0.49, 0.57]
T J Wang 2011	68	18	26	72	18	26	48.9%	-0.22 [-0.76, 0.33]
Total (95% CI)			**53**			**53**	**100.0%**	**-0.09 [-0.47, 0.30]**

Heterogeneity: Chi² = 0.45, df = 1 (P = 0.50); I² = 0%
Test for overall effect: Z = 0.44 (P = 0.66)

Std. Mean Difference IV, Fixed, 95% CI

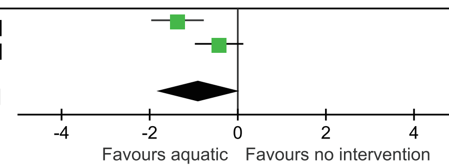


Comparsion 2. KOOS symptom : aquatic exercise versus no intervention

Study or Subgroup	no intervention Mean	SD	Total (n)	aquatic exercise Mean	SD	Total (n)	Weight	Std. Mean Difference IV, Random, 95% CI
H Lund 2008	61.4	2.3	27	64.6	2.31	27	49.2%	-1.37 [-1.97, -0.77]
T J Wang 2011	61	17	26	69	20	26	50.8%	-0.42 [-0.97, 0.13]
Total (95% CI)			**53**			**53**	**100.0%**	**-0.89 [-1.81, 0.04]**

Heterogeneity: Tau² = 0.36; Chi² = 5.19, df = 1 (P = 0.02); I² = 81%
Test for overall effect: Z = 1.88 (P = 0.06)

Std. Mean Difference IV, Random, 95% CI

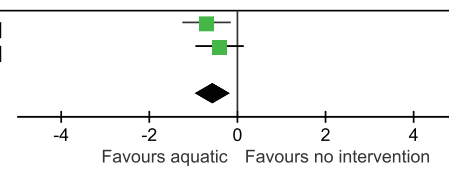


Comparsion 3. KOOS ADL : aquatic exercise versus no intevention

Study or Subgroup	no intervention Mean	SD	Total (n)	aquatic exercise Mean	SD	Total (n)	Weight	Std. Mean Difference IV, Fixed, 95% CI
H Lund 2008	61.1	2.2	27	62.7	2.3	27	49.9%	-0.70 [-1.25, -0.15]
T J Wang 2011	69	18	26	76	16	26	50.1%	-0.40 [-0.95, 0.14]
Total (95% CI)			**53**			**53**	**100.0%**	**-0.55 [-0.94, -0.16]**

Heterogeneity: Chi² = 0.56, df = 1 (P = 0.46); I² = 0%
Test for overall effect: Z = 2.78 (P = 0.005)

Std. Mean Difference IV, Fixed, 95% CI

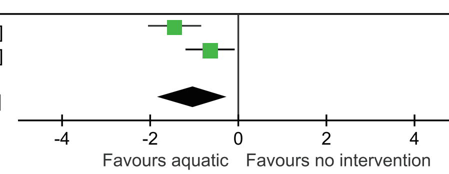


Comparsion 4. KOOS sport&rec : aquatic exercise versus no intevention

Study or Subgroup	no intervention Mean	SD	Total (n)	aquatic exercise Mean	SD	Total (n)	Weight	Std. Mean Difference IV, Random, 95% CI
H Lund 2008	21.8	3	27	26.2	3	27	48.9%	-1.45 [-2.05, -0.84]
T J Wang 2011	57	20	26	70	20	26	51.1%	-0.64 [-1.20, -0.08]
Total (95% CI)			**53**			**53**	**100.0%**	**-1.03 [-1.82, -0.25]**

Heterogeneity: Tau² = 0.24; Chi² = 3.68, df = 1 (P = 0.06); I² = 73%
Test for overall effect: Z = 2.57 (P = 0.01)

Std. Mean Difference IV, Random, 95% CI



Comparsion 5. KOOS Qol : aquatic exercise versus no intevention

Study or Subgroup	no intervention Mean	SD	Total (n)	aquatic exercise Mean	SD	Total (n)	Weight	Std. Mean Difference IV, Fixed, 95% CI
H Lund 2008	43.1	2.3	27	43	2.4	27	51.7%	0.04 [-0.49, 0.58]
T J Wang 2011	67	13	26	73	12	26	48.3%	-0.47 [-1.02, 0.08]
Total (95% CI)			**53**			**53**	**100.0%**	**-0.21 [-0.59, 0.18]**

Heterogeneity: Chi² = 1.73, df = 1 (P = 0.19); I² = 42%
Test for overall effect: Z = 1.06 (P = 0.29)

Std. Mean Difference IV, Fixed, 95% CI

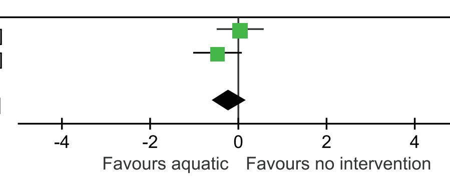


Figure 7. Forest plot of AQE versus CON interventions in all outcomes.

$P=.83$), KOOS pain (SMD: −0.15, 95% CI [−0.49, 0.20], $P=.40$), KOOS symptom (SMD: −0.23, 95% CI [−0.57, 0.11], $P=.19$), KOOS ADL (SMD: −0.16, 95%CI [−0.51, 0.18], $P=.35$), KOOS sport&rec (SMD: 0.74, 95% CI [−0.95, 2.44], $P=.39$), or KOOS QOL (SMD: 0.20, 95% CI [−0.15, 0.54], $P=.26$). The pooled results revealed that there was no significant difference between AQE and LBE groups in knee OA long-term outcomes (Fig. 8).

3.4. Adverse events

Three of the 8 studies reported mild adverse effects in the AQE group, including pain,[29,30] dyspnea,[29] and dizziness.[28] However, the adverse effects were more frequent and severe for the LBE group. One mentioned a 44% incidence of adverse effects in the LBE group, including pain and joint swelling; 3 participants even dropped out,[30] another record reported 2 patients increased pain after exercise.[28]

3.5. Publication bias analysis

The sample size of this meta-analysis was too small to detect publication bias via a funnel plot.

3.6. Level of evidence

The quality of the RCTs was assessed using the modified Jadad scoring system. A score of ≥4 was obtained for 6 studies[27–31,33] and 2 studies scored <3.[16,32] According to these results, the majority of the studies included can be considered to be high quality.

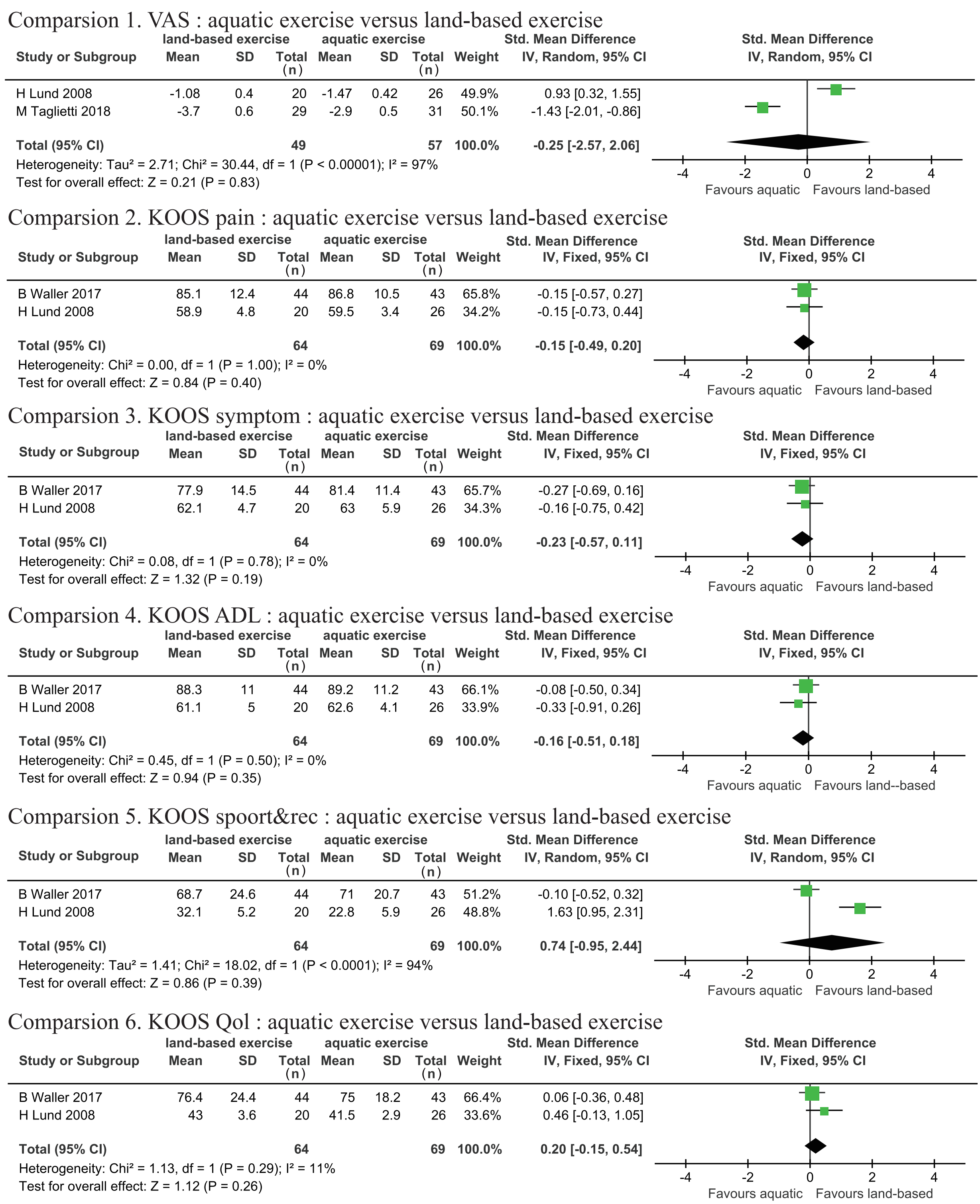


Figure 8. Forest plot of aquatic exercise (AQE) vs land-based exercise (LBE) interventions in long-term outcome.

4. Discussion

Increasing evidence suggests that knee OA is not only a type of joint disorder, but it is also a risk factor for other diseases.[34–36] Patients with painful knee OA have a higher risk of cardiovascular disease-specific and all-cause mortality compared to non-OA individuals.[37] Furthermore, substantial medical resources and costs are involved in the treatment of knee OA, so there is an urgent need to explore methods of slowing down or even attenuating the progression of this disease. LBE is a highly cost-effective method for treating knee OA, as patients are often obese and they have poor muscle strength. Regular exercise can efficiently decrease fat mass[29] while enhancing muscular strength. AQE describes an environment for structured physical activity rather than a type of exercise.[38] It has many advantages compared to LBE, and it is also recommended for post-total knee arthroplasty patient rehabilitation.[39,40] Accordingly, we hypothesized that AQE would be more effective than LBE in improving pain and physical function associated with knee OA.

This review synthesized data from 8 trials and summarized the effectiveness of AQE compared to LBE in the treatment of knee OA. For all of the assessment outcomes, no statistically significant differences were found between the 2 interventions over a short period of time, which is consistent with previous studies.[41,42] Furthermore, assessments conducted over a long period of time showed that AQE was comparable to LBE in the treatment of knee OA. The effectiveness of AQE compared to no intervention was also analyzed, although there were limited data. The results indicated that AQE had little effect on pain management and improvement of QOL, and only a small effect on the improvement of physical function.

Although blinding of the participants was impossible due to the nature of the interventions, 3 quarters of the included trials were deemed to be of high quality according to the modified Jadad score. The results indicated that there were no significant differences in pain relief between the 2 interventions. However, a single study involving an 18 week intervention, showed that AQE significantly decreased pain (measured using a VAS) before and after a 50-foot Walk Test compared to LBE.[16] Two studies also reported that AQE significantly improved walking speed compared to LBE.[28,29] This review showed only mild adverse effects in the AQE group after the intervention and no participants dropped out of this group. Thus, a high level of adherence and satisfaction for this type of intervention is indicated.

The lack of effectiveness may be ascribed to the heterogeneity of the included studies. Following a review of the characteristics of each study, various factors may have affected data collation and analysis, including: the age and body mass index of the patients, the diagnostic criteria and disease stage, the prescription and duration of exercise, and the use of different outcome assessments. The exercise prescription appeared to be the greatest source of heterogeneity. All of the 8 records included in this study reported totally different exercise prescriptions. Although the majority of the prescribed exercises consisted of strength and aerobic training, different exercise programs and durations may exert different effects. In addition, the thermal energy, resistance, and buoyancy provided by the water at different temperatures and depths may also directly impact the exercise outcomes.

The AQE interventions consist of many factors. Since the 1930s, it has been suggested that regulation of the dosage, character, frequency, and duration of AQE may be beneficial for restoring muscle function; however, relevant guidelines are still unavailable. For example, the optimal exercise mode, intensity, duration and frequency, and the optimal water characteristics (i.e., temperature and depth) are still unclear. Various modes of AQE have shown positive effects on knee OA symptoms and function[43–45]; however, the most efficient type or combination of AQE is still unknown. The intensity of an exercise program is typically described as high, moderate, or low. The effect of exercise intensity on the efficacy of interventions cannot be ignored, even though a recent study reported no significant difference between high-intensity and low-intensity exercise programs on improving pain and physical function in the short term.[46] The assessment of AQE intensity is quite different to LBE due to water resistance and buoyancy. Compared to LBE, the same effect on aerobic capacity may therefore be achieved with a lower intensity of AQE.[15] The precise assessment and management of AQE intensity remains to be elucidated.

Water properties, such as temperature and depth, are important in AQE. A temperature range of 33.5°C to 35.5°C is suitable because it allows lengthy immersion and thus enables sufficient exercise to be performed to achieve therapeutic effects without participants becoming cold or over-heating.[15] Different depths of water provide different buoyancy effects. A greater water depth may significantly reduce joint load-bearing by improving buoyancy.[47] Three of the included trials described a water depth of 1.15 to 1.2 m. When immersed to the xiphoid, approximately 50% of body weight is offloaded. One trial reported a water depth of 1.5 m, with immersion almost to the cervical region. In this study, the buoyancy would counteract approximately 60% of body weight. There is no doubt that all of the above-mentioned factors will increase the heterogeneity of clinical outcomes. Therefore, to facilitate the development of AQE guidelines, we recommend that future studies include detailed descriptions of the exercise program used, including the exercise mode, intensity and duration, and the water temperature and depth. High-quality, multi-center, large-sample RCTs are also required to evaluate the efficiency and safety of AQE for knee OA.

4.1. Limitation

There are several limitations of this review. Firstly, the inclusion of only a small number of studies with limited sample size, precluded the ability to draw definitive conclusions. In addition, all of the records failed to include an estimation of sample size. Secondly, all of the included studies used different modes and durations of AQE. Variations in the exercise program may potentially affect its efficiency and outcomes. Thirdly, due to the nature of the intervention, sufficient blinding was impossible to achieve.

5. Conclusion

Overall, AQE and LBE show comparable effects for treating knee OA. The results of this meta-analysis favored neither AQE nor LBE interventions for improving pain relief, physical function, and QOL both in the short and long term. Compared to no exercise, AQE can effectively improve physical function. We failed to provide a convincing conclusion due to the small sample of patients and the limited number of appropriate research studies. Further high quality RCTs with long follow-up periods are required.

Acknowledgment

The authors thank the National Natural Science Foundation of China and Zhejiang Chinese Medical University for their funds and support.

Author contributions

Conceptualization: Peijian Tong.
Data curation: Shibing Xu, Lei Zhang.
Formal analysis: Yunyao Wu.
Funding acquisition: Hongting Jin.
Investigation: Rui Dong, Peijian Tong.
Methodology: Rui Dong, Hongting Jin.
Resources: Peijian Tong.

Software: Yunyao Wu, Jun Ying.
Validation: Rui Dong, Peijian Tong.
Writing – original draft: Rui Dong, Yunyao Wu.
Writing – review & editing: Pinger Wang, Luwei Xiao, Peijian Tong.

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