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REVIEW ARTICLE (META-ANALYSIS)

Early Aquatic Physical Therapy Improves Function and Does Not Increase Risk of Wound-Related Adverse Events for Adults After Orthopedic Surgery: A Systematic Review and Meta-Analysis

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Abstract

Objectives: To investigate whether early postoperative aquatic physical therapy is a low-risk and effective form of physical therapy to improve functional outcomes after orthopedic surgery.

Data Sources: Databases MEDLINE, CINAHL, AMED, Embase, and PEDro were searched from the earliest date available until October 2011. Additional trials were identified by searching reference lists and citation tracking.

Study Selection: Controlled trials evaluating the effects of aquatic physical therapy on adverse events for adults <3 months after orthopedic surgery. Two reviewers independently applied inclusion and exclusion criteria, and any disagreements were discussed until consensus could be reached. Searching identified 5069 potentially relevant articles, of which 8 controlled trials with 287 participants met inclusion criteria.

Data Extraction: A predefined data extraction form was completed in detail for each included study by 1 reviewer and checked for accuracy by another. Methodologic quality of included trials was assessed independently by 2 reviewers using the PEDro scale.

Data Synthesis: Pooled analyses were performed using random effects model with inverse variance methods to calculate standardized mean differences (SMDs) and 95% confidence intervals (CIs) (continuous outcomes) and risk difference and 95% CIs (dichotomous outcomes). When compared with land-based physical therapy, early aquatic physical therapy does not increase the risk of wound-related adverse events (risk difference=.01, 95% CI −.05 to .07) and results in improved performance of activities of daily living (SMD=.33, 95% CI=.07−.58, $I^2=0\%$). There were no significant differences in edema (SMD=−.27, 95% CI=−.81 to .27, $I^2=58\%$) or pain (SMD=−.06, 95% CI=−.50 to .38, $I^2=32\%$).

Conclusions: After orthopedic surgery aquatic physical therapy improves function and does not increase the risk of wound-related adverse events and is as effective as land-based therapy in terms of pain, edema, strength, and range of motion in the early postoperative period.

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The importance of early mobilization after orthopedic surgery has been well documented,[1-3] and there is evidence to suggest that the earlier subjects can commence mobilization and strengthening after orthopedic surgery, the quicker their return to functional activities.[2] Early mobilization, however, can be limited by pain and reduced muscle coordination, strength, and ability to bear weight in the early postoperative period.[4] In addition, an intensive land-based physical therapy program may result in high dropout rates in older adults.[5]

Hydrotherapy can be defined as exercise in warm water[6] and can be used for muscle strengthening, flexibility, cardiovascular fitness, and improved psychological effects.[7] The physical properties of water in a hydrotherapy pool make it a medium that provides the support and comfort in which to commence exercising in early rehabilitation postsurgery: buoyancy decreases apparent body weight[8,9] and lower limb internal joint forces,[10] allowing postoperative subjects to practice walking unaided in water early in their rehabilitation. Drag forces provide resistance to movement,[7,11] which allows the progression of exercises throughout rehabilitation. When immersed, the body has fluid pressure (which increases with depth) exerted on all surfaces.[12] The resulting hydrostatic pressure gradients produced during immersion cause a shift in fluid from the lower limbs to the cardiothoracic compartment, which can result in a reduction of edema in the legs.[13,14]

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The aquatic environment can therefore be used to regain mobility, strengthen muscles, commence early weight bearing, and help reduce pain and perceived discomfort,[3] allowing the subject to achieve more than he or she usually can on land and may even eliminate the need for any other form of physical therapy.[15] A systematic review comparing the effects of aquatic physical therapy and land-based exercise for people with arthritis found that aquatic exercise was comparable to land-based exercise in terms of functional outcomes and recommended aquatic physical therapy as an alternative to land-based physical therapy when people are unable to exercise comfortably on land.[16]

Despite the rationale for early aquatic physical therapy in rehabilitation and anecdotal popularity with subjects,[17] there is conflicting information on how soon wounds can be immersed after orthopedic surgery and when the optimal time to commence aquatic physical therapy is. Some recommend that subjects must wait until 2 weeks postoperation to allow for wounds to heal,[18,19] others suggest that subjects be allowed to submerge in water 1 week after surgery,[1] and yet others have documented that it is common practice to commence aquatic physical therapy as early as 4 days postoperatively.[15,20,21]

Precautions and contraindications associated with aquatic physical therapy may explain some of the variability in recommendations found in the literature. For example, open wounds are contraindicated[22] (but may be immersed if they are covered with an occlusive waterproof dressing[23]) because there may be concerns for delayed wound healing and increased susceptibility of wound infections.[24] In addition, the physiological changes that occur during immersion such as increased central blood volume due to hydrostatic pressure gradients[6] means that certain medical conditions such as cardiovascular disease may contraindicate aquatic therapy or require modification of the program for subject comfort and safety.[22]

Aquatic physical therapy, used alone or in combination with land-based physical therapy, is widely used as part of rehabilitation after orthopedic surgery[2,17]; however, we were unable to locate any reviews that have synthesized data on the risks and effects of early aquatic physical therapy within 3 months after orthopedic surgery. A systematic review completed in 2002 concludes that there exists high- to moderate-quality evidence on the benefits of aquatic physical therapy for adults with rheumatic conditions and chronic low back pain but adds that aquatic physical therapy after orthopedic surgery has "received little attention from researchers to date."[17(p519)] Adverse events after aquatic therapy are not well documented, and it is not clear whether there is a risk difference (RD) between aquatic physical therapy and land-based physical therapy. Therefore, the research questions for this review were: is early aquatic physical therapy for adults after orthopedic surgery low risk in terms of wound-related adverse events and beneficial (in regard to reducing impairment and increasing activity and participation) when compared with land-based physical therapy?

List of abbreviations:

ACL	**anterior cruciate ligament**
ADL	**activities of daily living**
CI	**confidence interval**
QOL	**quality of life**
RD	**risk difference**
ROM	**range of motion**
SMD	**standardized mean difference**
THR	**total hip replacement**
TKR	**total knee replacement**

Methods

This review was conducted and reported with reference to PRISMA[25] guidelines for high-quality reporting of systematic reviews and meta-analyses and has been registered with PROSPERO (registration no.: CRD42011001587 www.crd.york.ac.uk).

Identification and selection of trials

Relevant articles were identified using a search method with 2 main constructs ("aquatic physical therapy" and "orthopedic surgery") and using synonyms for these terms (appendix 1) to search the following databases from the earliest date available until October 2011: MEDLINE, CINAHL, AMED, Embase, and PEDro. A reviewer (E.V.) also manually searched reference lists of included articles and of reviews in the field of aquatic physical therapy and completed citation tracking (via Google Scholar) to ensure that all relevant studies were captured. The search was limited to English-language texts. Two reviewers independently screened titles and abstracts of the studies retrieved and applied the inclusion and exclusion criteria (table 1). Any that clearly did not fulfill the criteria were excluded. Where it was not clear, the full-text articles were obtained for detailed examination. When the full text was obtained, second-stage screening was performed independently by 2 reviewers and any disagreements were resolved by discussion between the 2 reviewers until consensus was reached. If a consensus could not be reached, a third party was consulted.

Inclusion criteria

The trials needed to be controlled trials published in a peer review journal involving adult participants (≥18y old) in the early postoperative period (≤3mo) after any orthopedic surgery. The trials had to compare aquatic physical therapy with land-based physical therapy. For the purpose of this review, aquatic physical therapy refers to any water-based therapy as described by Bartels et al.[26] This may include stretching, strengthening, range of motion (ROM), and aerobic exercises. Studies were excluded if the participants had not had orthopedic surgery, if treatment occurred after the early postoperative period (more than 3mo postoperatively), if they included a healthy (nonmatched) comparison group, if they did not use aquatic physical therapy as a treatment modality, and if data on adverse events could not be obtained. Authors of studies without published data on adverse events were contacted directly to obtain this information and where authors responded, these (unpublished) data were included in the review.

Assessment of characteristics of trials

Quality assessment of trials and risk of bias

Quality of the studies was assessed using the 10-point scale of the Physiotherapy Evidence Database (PEDro, www.pedro.org.au): a validated quality assessment tool for randomized controlled trials.[27] The PEDro scale assesses bias in clinical trials by scoring items such as concealed allocation, patient and therapist blinding, and use of intention-to-treat analysis. Two reviewers

Table 1 Inclusion criteria

Design	
	• Controlled trial
	• English text
	• Published in peer-reviewed journal
Participants	
	• Adults aged ≥18y old
	• ≤3mo after any orthopedic surgery
Intervention	
	• Aquatic physical therapy
Outcome measures	
	• Adverse events
	• Measures of function, activity, or participation
Comparisons	
	• Aquatic physical therapy versus appropriately matched (ie, postsurgical) land-based physical therapy

independently applied the criteria to each article. Interrater agreement was recorded, and any disagreement was resolved through discussion between the 2 reviewers. Where consensus could not be reached, a third reviewer was consulted. Trials were not excluded on the basis of quality; however, this was taken into account when interpreting the results.

Data extraction

A customized data extraction form was developed (available on request) on the basis of Cochrane Consumers and Communication Review Group's Data Extraction form.[28] The form was completed in detail for each included study by 1 reviewer (E.V.) and checked for accuracy by another reviewer (C.P.). If any discrepancies were evident, the reviewers referred back to the original trial report. Attempts were made to contact the authors of any trial with missing data. Information was extracted from each trial on participant characteristics (age, details of orthopedic surgery undergone), trial setting (inpatient, outpatient), intervention (type, duration, frequency, and when commenced), outcomes (primary and secondary outcomes, timing of assessment), and adverse events.

Outcomes

The primary outcome was adverse events in relation to wound healing. For the purpose of this review, adverse events were defined as any event resulting in a deep or superficial surgical site infection or delayed wound healing. Any reported adverse events that were not associated with the wound site were not included in the analysis (eg, symptomatic anemia).

Where authors did not specify the type of adverse event they had investigated, the entire number of adverse events was used in analysis. RD was used to measure the difference in the observed risk of events between the aquatic and land-based groups and was chosen because it could be used even when there were no adverse events in either group.[29] Secondary outcomes were measures of impairment (edema, pain, strength, and ROM), activity (activities of daily living [ADL]), and participation, as indicated by quality of life (QOL).

Edema and pain are common after orthopedic surgery and can impede recovery[1]; thus, it is important to control these factors to enable subjects to participate fully in their rehabilitation program to regain function. Strength and ROM will play a major role in determining functional capacity and are important outcomes to assess after therapy to monitor treatment effect. ADL were selected because the main aim of rehabilitation is to help subjects reach their functional goals and achieve independence as much as possible. QOL can cover broad domains such as physical and psychological health, social relationships, and the environment[30] and can be used as a measure of participation in life situations important to the individual.

Data analysis

Data were synthesized by using postintervention means and SDs, and meta-analyses were completed where possible. Meta-analyses were performed using a random effects model for outcomes using inverse variance methods using RevMan (version 5.0).[a] Trial results were pooled only if they measured similar outcomes. Statistical heterogeneity was assessed using the I^2 statistic, with values of more than 50% representing substantial levels of heterogeneity.[31] Where substantial levels of heterogeneity were present, subgroup analyses were performed post hoc to attempt to explain the heterogeneity—for example, by separating different measuring techniques when assessing edema. Meta-analysis of dichotomous outcomes (presence or absence of adverse events) was expressed as an RD and 95% confidence interval (CI) and for continuous outcomes was expressed as a standardized mean difference (SMD) and 95% CI. Where weighted means were calculated, they were weighted according to participant numbers.

Results

Study selection

The initial database search yielded 5067 articles. Two additional articles were identified through reference scanning and citation tracking.[32,33] After removal of duplicates, 3493 studies were screened on title and abstract. There was very good agreement between reviewers ($\kappa = .81$, 95% CI $= .67-.95$) in regard to which trials did and did not fulfill selection criteria. Full-text copies of 20 studies were retrieved for further analysis. When evaluating the full-text trials, consensus was reached to retain a total of 8 trials for inclusion in the systematic review (fig 1).

Characteristics of included trials

Methods

All 8 trials included in the review were controlled trials, of which 5 were randomized controlled trials. The included trials had a mean PEDro score of 5.3, ranging from 2[34] to 8.[18] None of the included studies had participant or therapist blinding. Four studies used random allocation, 3 used concealed allocation, 5 had blinded assessors, and all used intention-to-treat analysis except for 2.[32,34] (PEDro quality assessment table is available on request.) There was good agreement between reviewers when rating individual items on the PEDro scale ($\kappa = .78$, 95% CI $= .64-.92$).

Participants

The review included 287 participants (55% women), of whom 146 received aquatic physical therapy treatment (51%). Participants had a weighted mean age of 65 years. One trial included adults after rotator cuff repair (n = 18), 2 trials included adults after anterior cruciate ligament (ACL) reconstruction (n = 30), 2 trials included adults after total hip replacement (THR), 2 trials included adults after total knee replacement (TKR), and 1 trial included a combination of adults after THR and TKR (THR n = 87, TKR n = 152). Some of the participants post-ACL reconstruction were in a younger age bracket than the other participants with an age range of 18 to 88 years[32,34] (table 2).

Intervention

In all trials, 1 group received aquatic physical therapy while the control group received land-based physical therapy only. In 4 trials,[20,21,35,36] the aquatic physical therapy group received a combination of land and aquatic physical therapy; participants in 1 study undertook aquatic therapy followed by land-based therapy[36]—the other 3 studies did not specify the order in which they structured their programs. Three trials reported that they used individualized programs different from land-based exercises for subjects in the aquatic group,[20,21,35] while the rest of the trials reported that the aquatic group participants performed the same exercises that the land-based participants did, in the pool rather than on land. Three trials provided individual 1:1 aquatic physical therapy,[20,21,32] and the others provided group sessions only. The 4 studies[21,34-36] that described their aquatic exercise programs all used equipment in the aquatic environment.

The programs ran between 2 and 3 times per week for 6 to 12 weeks and were well matched in terms of the amount of therapy provided for control and experimental groups within each study.

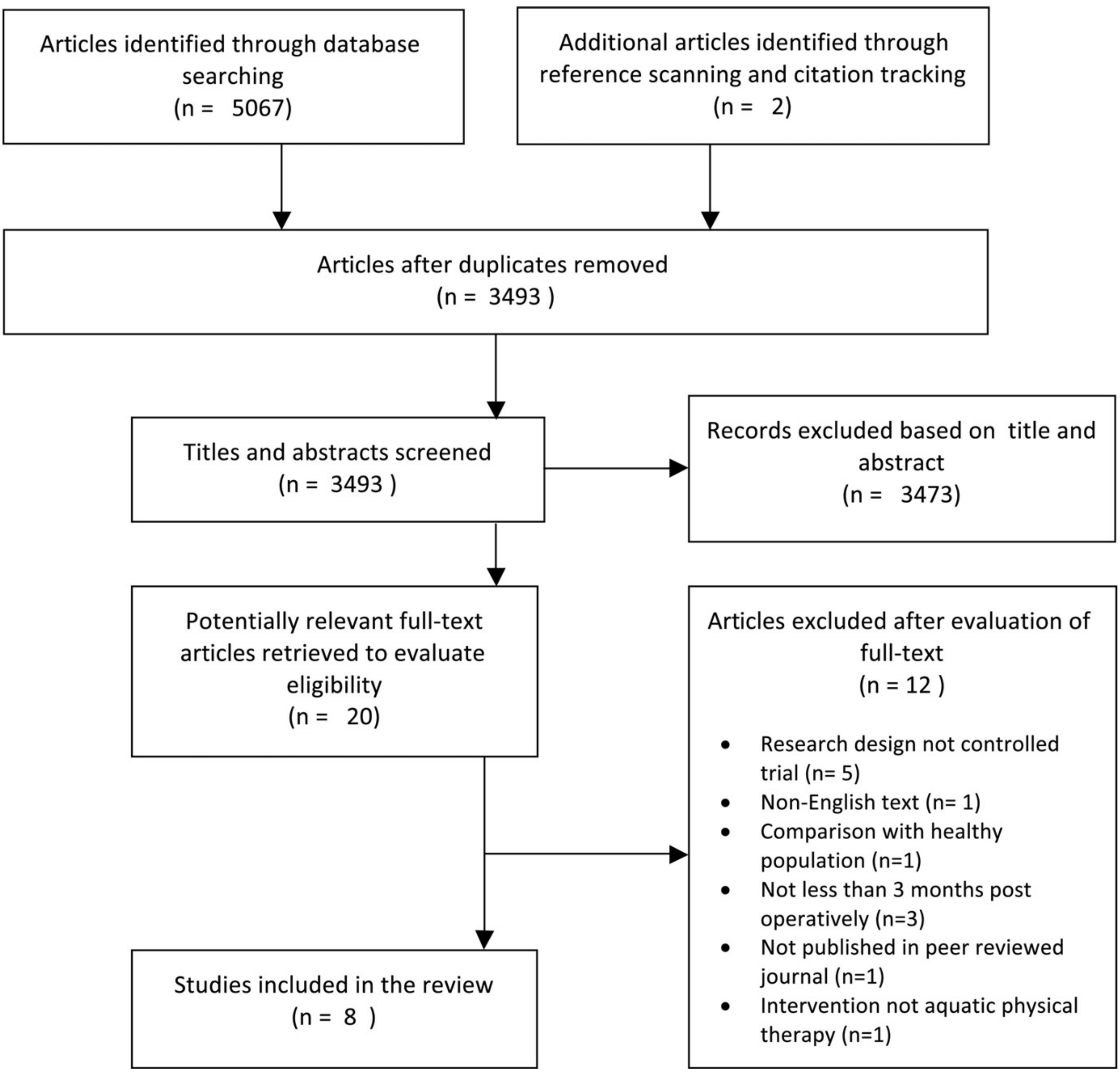

Fig 1 Flow of studies through the review.

Table 2 Summary of included studies (n=8)

Authors	Patient Health Condition	Setting	Design	PEDro Score	No. of Participants (Aquatic/ Land)	Mean Age (y) (Aquatic/ Land)	Days Postoperative When Commenced Aquatic Therapy	Aquatic Therapy Group	Land-Based Group	Outcomes
Brady[35]	Rotator cuff repair	Outpatient	Controlled trial	6	12/6	56.3/53.5	10	Delivery: Group Frequency: 2× week Duration: 12/52 Additional land therapy: YES	Delivery: 1:1 Frequency: 2× week Duration: 12/52	Adverse events HRQOL (WORCI) PROM shoulder F and ER
Harmer[18]	TKR	Outpatient	RCT	8	53/49	68.7/67.8	14	Delivery: Group Frequency: 1 h 2× week Duration: 6/52 Additional land therapy: NO	Delivery: Group Frequency: 2× week Duration: 6/52	Adverse events 6-min walk test Stair-climbing power WOMAC PROM knee Edema (circumference)
Jakovljevic and Vauhnik[33]	THR	Inpatient	Controlled trial	5	12/12	83.7/82	14—21	Delivery: Group Frequency: 45 min 3× week Duration: 8/52 Additional land therapy: NO	Delivery: Group Frequency: 45 min 3× week Duration: 8/52	Adverse events TUGT(s) Harris Hip Score: total, pain, function, and motion
McAvoy[36]	TKR	Outpatient	RCT	6	15/15	ND	ND	Delivery: Group Frequency: 30 min 2× week Duration: 6/52 Additional land therapy: YES	Delivery: Group Frequency: 60 min 2× week Duration: 6/52	Pain (NPRS) Edema (circumference) Knee AROM and PROM KOOS (Symptoms, QOL, ADL)
Stockton and Mengersen[20]	THR	Inpatient acute hospital	Controlled trial	6	21/27	65.5/62.8	4	Delivery: 1:1 Frequency: daily Duration: until discharge. Additional land therapy: YES	Delivery: 1:1 Frequency: daily Duration: until discharge	Iowa Level of Assistance
Rahmann[21]	THR and TKR	Inpatient acute hospital	RCT	5	18/17	69.4/70.4	4	Delivery: 1:1 Frequency: daily Duration: until discharge Additional land therapy: YES	Delivery: 1:1 Frequency: 40 min 1× daily Duration: until discharge	Adverse events 10m walk WOMAC Quads, Hamstrings, and Hip abd strength (HHD) AROM knee flex Edema (circumference) PSFS

(*continued on next page*)

Table 2 (*continued*)

Authors	Patient Health Condition	Setting	Design	PEDro Score	No. of Participants (Aquatic/Land)	Mean Age (y) (Aquatic/Land)	Days Postoperative When Commenced Aquatic Therapy	Aquatic Therapy Group	Land-Based Group	Outcomes
Tovin[34]	ACL reconstruction	Outpatient	RCT	2	10/10	29/29	14	Delivery: ND Frequency: 3× week Duration: 6/52 Additional land therapy: NO	Delivery: ND Frequency: 3× week Duration: 6/52	Function (Lysholm scale) Edema (circumference) Knee flex strength Knee ext strength
Zamarioli[32]	ACL reconstruction	Outpatient	RCT	4	5/5	ND	ND	Delivery: 1:1 Frequency: 50 min 2× week Duration: 9/52 Additional land therapy: NO	Delivery: 1:1 Frequency: 50 min 2× week Duration: 9/52	Adverse events Pain (NPRS) Edema (circumference) Knee flex strength Knee ext strength Knee PROM flex and ext

Abbreviations: Abd, abduction; AROM, active range of motion; ext, extension; flex, flexion; HRQOL, health-related quality of life; KOOS, Knee Osteoarthritis Outcome Score; ND, no data; NPRS, Numeric Pain Rating Scale; PROM, passive range of motion; PSFS, Patient Specific Functional Scale; Quads, quadriceps muscle; RCT, randomized controlled trial; shoulder F and ER, shoulder flexion and external rotation; TUGT, timed up and go test; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; WORCI, Western Ontario Rotator Cuff Index.

There was no difference between the aquatic group and the land-based group in terms of adherence rates in any of the studies included. The studies that ran their program twice a week went for 6 weeks,[18,36] 9 weeks,[32] and 12 weeks.[35] Two studies ran sessions daily until discharge from hospital.[20,21] Other studies ran sessions 3 times per week for 6 weeks[34] and 8 weeks.[33] Most studies progressed participants according to ability, strength, and ROM as required, and some specified altering the water depth in which participants exercised to challenge or assist the subject. Depth used was described as being from waist to chest deep (0.5−1.6m).[18,21,34]

Of the included studies, 2 of the trials commenced aquatic therapy at day 4 postoperatively,[20,21] 1 commenced aquatic therapy 10 days postoperation,[35] 3 commenced at day 14 post-surgery,[18,33,34] and 2 studies[32,36] did not specify how long post-operative aquatic therapy was commenced.

Outcomes measures

All included trials provided information on the number of adverse events related to wound healing. One study[18] also documented adverse events such as death and respiratory, cardiac, and other medical complications; however, these data were not used in our analysis because we were interested in surgical site infections and wound complications as our primary adverse outcomes measure.

Six studies measured ADL using a variety of measurement tools (Iowa Level of Assistance, Patient Specific Functional Scale, Lysholm scale and function/ADL subscales of Harris Hip Score, Knee Osteoarthritis Outcome Score, and the Western Ontario and McMaster Universities Osteoarthritis Index). Four studies measured edema (circumference), and 4 studies measured pain (Visual Analog Scale, Numerical Pain Rating Scale, and the pain subscales of Harris Hip Score and Western Ontario and McMaster Universities Osteoarthritis Index). Other impairment measures used were ROM of the operated joint (measured with a goniometer) and muscle strength (measured with a hand-held dynamometer or with manual muscle testing technique). QOL was measured using the Western Ontario Rotator Cuff Index, the QOL subscale of the Knee Osteoarthritis Outcome Score, and 2 subscales of the Arthritis Self-Efficacy scale (the self-efficacy to achieve outcomes and the self-efficacy to manage symptoms).

Effects of aquatic physical therapy versus land-based therapy

Attempts were made via e-mails to contact authors for missing data. Responses and additional data were received in 4 instances.[20,33,34,36]

Adverse events

Meta-analysis of 8 trials and 287 participants provided evidence that aquatic physical therapy did not increase the risk of wound-related adverse events compared with land-based therapy (RD=.01, 95% CI=−.05 to .07, I^2=0%) (fig 2).

Seven trials reported no adverse events for both the experimental and control groups during the length of their trial and follow-up period. One trial reported the number of deep and superficial surgical site infections, and there were no differences between groups in this trial.[18]

Activities of daily living

When compared with standard land-based physical therapy in 6 trials (n=134), aquatic physical therapy resulted in a significant

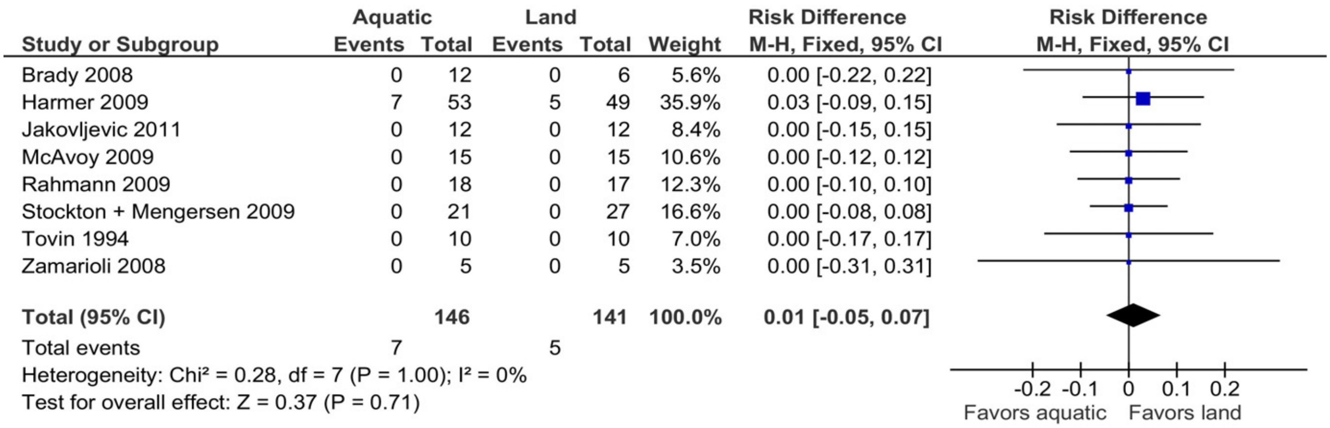

Fig 2 RD (95% CI) for the effect of aquatic physical therapy compared with land-based physical therapy on adverse events. Data obtained from 8 trials (n=287). Abbreviation: M-H, Mantel-Haenszel.

improvement in measures of ADL (SMD=.33, 95% CI=.07−.58, I^2 0%) (fig 3).

Pain

When comparing pain levels in 4 trials (n=149), the differences between groups did not reach statistical significance (SMD=−.06, 95% CI=−.50 to .38, I^2=32%) (fig 4).

Edema

When comparing the amount of edema in 4 trials (n=173), the differences between groups did not reach statistical significance (SMD=−.27, 95% CI=−.81 to .27, I^2=58%). There was a moderate degree of heterogeneity in the data. In 1 trial,[18] circumferential measurements were taken at 4 locations and averaged to obtain the edema measurement while the other 3 trials used 1 measurement closer to the knee joint. When this trial[18] was removed from the analysis, aquatic physical therapy resulted in significantly reduced edema (SMD=−.58, 95% CI=−1.05 to −.11, I^2=0%) (fig 5).

Muscle strength

There was no statistically significant difference in knee extension or flexion strength between the aquatic and land-based groups in the 2 trials reporting on effects post-ACL reconstruction.[32,34] One trial on adults after THR and TKR reported increased knee extension strength (*P*=.03) and significantly increased hip abduction strength (*P*=.001) when compared with land-based physical therapy after 2 weeks of aquatic physical therapy commenced at 4 days postoperation.[21] One study used stair-climbing power as a measure of strength and reported that both the aquatic group and the land-based group improved over time; however, the aquatic group demonstrated significantly more improvement than the land-based group between 8 and 26 weeks postsurgery (*P*=.005).[18]

Joint ROM

Seven trials recorded joint ROM. These were not combined into a meta-analysis because there was clinical heterogeneity in joints measured and surgical procedures. Brady et al[35] reported that the aquatic physical therapy group made significantly more improvement in shoulder flexion range than did the land-based physical therapy group after rotator cuff repair at 3 and 6 weeks postoperatively (*P*=.005 and .01, respectively), and McAvoy[36] reported that subjects in the aquatic physical therapy group had significantly greater improvements in knee flexion active ROM after total knee arthroplasty (*P*=.045) compared with land-based therapy only. The other 5 trials found no significant differences between the aquatic therapy group and the land-based therapy group in terms of ROM.[21,32-34,36]

Quality of life

The 3 studies that measured QOL found no significant differences between the aquatic and land-therapy groups when assessing QOL. These were not combined in a meta-analysis because of heterogeneity in the outcome measures used.

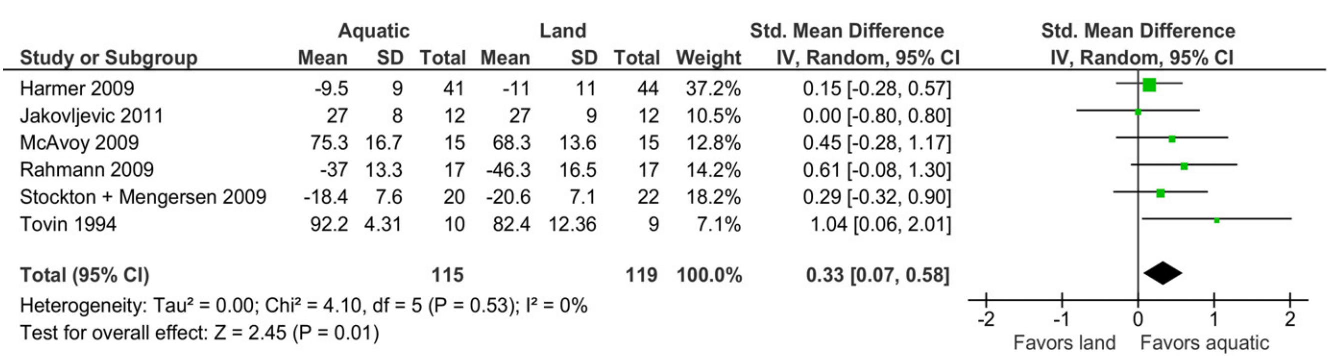

Fig 3 SMD (95% CI) for the effect of aquatic physical therapy on ADL by pooling data from 6 trials (n=134). Abbreviations: IV, inverse variance; Std., standard.

Study or Subgroup	Aquatic Mean	Aquatic SD	Aquatic Total	Land Mean	Land SD	Land Total	Weight	Std. Mean Difference IV, Random, 95% CI
Harmer 2009	3.5	3.5	44	2.5	3	41	44.2%	0.30 [-0.12, 0.73]
Jakovljevic 2011	-35	9	12	-33	6	12	21.4%	-0.25 [-1.06, 0.55]
McAvoy 2009	60.8	15.8	15	63.5	12	15	25.1%	-0.19 [-0.90, 0.53]
Zamarioli 2008	0.001	0.001	5	1.8	2.4	5	9.3%	-0.96 [-2.31, 0.39]
Total (95% CI)			**76**			**73**	**100.0%**	**-0.06 [-0.50, 0.38]**

Heterogeneity: Tau² = 0.07; Chi² = 4.44, df = 3 (P = 0.22); I² = 32%
Test for overall effect: Z = 0.25 (P = 0.80)

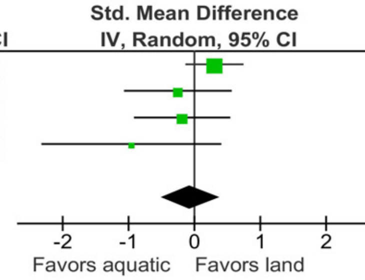

Fig 4 SMD (95% CI) for the effect of aquatic physical therapy on pain by pooling data from 4 trials (n=149). Abbreviations: IV, inverse variance; Std., standard.

Discussion

The results from this systematic review provide evidence from 8 controlled trials, with 287 participants, that there was no increased risk of wound-related adverse events for subjects undertaking aquatic physical therapy in the early postoperative period after orthopedic surgery compared with land-based therapy. This is in accordance with results from Giaquinto et al[37,38] who reported that an aquatic program had significantly fewer adverse events compared with a land-based program in subjects after TKR and THR. A recent randomized controlled trial concluded that early aquatic physical therapy (commenced day 6 postoperatively) leads to clinically important improvements in health-related QOL for adults after TKR and resulted in slight increases in adverse events for adults after THR when compared with aquatic physical therapy commenced at day 14.[39] Both groups in this trial actually started aquatic physical therapy quite early postoperatively (at day 6 or day 14).

There is electromyographic evidence that exercising in water after shoulder injury such as rotator cuff tear can be considered relatively safer than exercising on land because of the reduction in muscle activity levels when immersed[40] and that immersion of limbs with external fixators does not increase the rate of adverse events.[24,41] However, in practice, orthopedic surgeons and physical therapists alike are still reluctant to immerse an orthopedic wound in the early postoperative period for fear of reduced wound healing and/or surgical site infection.[24] After THR or TKR, the rate of deep surgical site infection is between 0.2% and 2.7%.[42,43] Up-to-date infection rates are not well reported in the literature; however, infections were reported to be between 2.1% and 7.1% in 1991.[44] This review provides evidence that there is no increased risk of infection or other adverse events when immersing a wound as early as 4 days after orthopedic surgery[20,21] as long as it is covered with an appropriate waterproof dressing that is able to conform to the area in question and allow full movement.[1,21] Dressings were checked prior to immersion and changed as soon as possible on return to the ward as per an immersion protocol in 1 study.[21] For outcomes such as surgical site infection, very large samples may be needed before it can confidently be said that aquatic physical therapy is safe. Even though information on adverse events was collected on a relatively small number of subjects in this review, participants took part in a combined total of 1779 aquatic physical therapy sessions with no increased risk of adverse events.

When compared with standard land-based physical therapy, aquatic therapy resulted in a significant improvement on measures of ADL. Improvement in ADL has also been noted after participation in an aquatic therapy program in older adults with arthritis.[45] This is a clinically significant finding because the ability to perform ADL with less pain and difficulty is a major priority for the older population with arthritis.[46]

It was hypothesized that participants in the aquatic therapy group would demonstrate an even greater effect in terms of reduced swelling compared with the control group because of the effects of hydrostatic pressure in water, but this hypothesis was not supported by our results. There was no significant difference between the aquatic group and the land-based group in terms of swelling or edema; however, both groups demonstrated an improvement in swelling over time, suggesting that early mobilization in either an aquatic environment or a land environment will result in reduced swelling via the pumping action of the involved muscles and that the possible expected hydrostatic effects of immersion may be counteracted by the dilation of vessels due to the water's warm temperature.

Study or Subgroup	Aquatic Mean	Aquatic SD	Aquatic Total	Land Mean	Land SD	Land Total	Weight	Std. Mean Difference IV, Random, 95% CI
Harmer 2009	45	4	50	44	5	49	36.3%	0.22 [-0.18, 0.61]
McAvoy 2009	42.9	6.1	15	46.6	6	15	24.6%	-0.60 [-1.33, 0.14]
Rahmann 2009	42.9	3	17	46.5	6.3	17	25.8%	-0.71 [-1.41, -0.02]
Zamarioli 2008	39.3	3.8	5	39.7	1.7	5	13.3%	-0.12 [-1.36, 1.12]
Total (95% CI)			**87**			**86**	**100.0%**	**-0.27 [-0.81, 0.27]**

Heterogeneity: Tau² = 0.17; Chi² = 7.22, df = 3 (P = 0.07); I² = 58%
Test for overall effect: Z = 0.97 (P = 0.33)

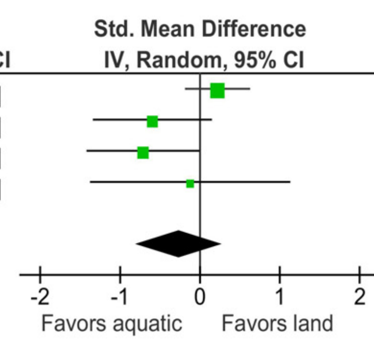

Fig 5 SMD (95% CI) for the effect of aquatic physical therapy on edema by pooling data from 4 trials (n=173). Abbreviations: IV, inverse variance; Std., standard.

Although all trials demonstrated an improvement in muscle strength over time, this review found no significant differences between the aquatic and land-based groups in terms of strength and mobility in the early postoperative period for most of the trials. However, Rahmann et al[21] found strength benefits to be evident as early as 2 weeks postoperatively when aquatic physical therapy was commenced 4 days postoperatively. This study was different from other included studies because they had very early commencement of aquatic therapy and used 1:1 therapy with an experienced aquatic physical therapist trained to use the properties of water to produce maximal strength gains. These differences may have led to greater strength benefits observed in that trial.

There is evidence that aquatic exercise can be effective in reducing pain for adults suffering from back pain[47] and fibromyalgia.[48] However, we found no significant difference in terms of pain between the aquatic and land-based groups. Three of the 4 studies had a trend toward less pain after aquatic therapy; however, these studies each had small sample sizes and were of a medium quality. A recent systematic review found that aquatic therapy relieved pain for adults with neurologic and musculoskeletal disease when compared with no therapy but not when compared with land-based therapy[49] (which was the comparison made in our review).

Health-related QOL is a broad term that includes the subject's physical, mental, and social effects of illness and has been shown to improve after total hip and knee arthroplasty,[50] and this review did not find that QOL improvements were different between adults who completed aquatic physical therapy versus land-based physical therapy.

Study limitations

This review limited articles to English language; therefore, an English language bias is present. However, Wright et al stated that "the effect of language bias minimally impacts the conclusions of systematic reviews"[51(p25)]; thus, this is likely to be a minor limitation in this review. It was difficult, if not impossible, to establish the physical therapist's skills in assessment and aquatic therapy and how this may have had an impact on outcomes of the included trials. Because of the specialized nature of aquatic therapy and the need to understand the hydrodynamics of water, this skill may have an impact on how well participants do. Some studies also included a cointervention of land therapy[21,35,36] that made it difficult to interpret results and establish what part of the treatment was causing the effect seen; however, this replicates clinical practice. There was only 1 study investigating the effects after an upper limb intervention; thus, these findings are more characteristic for subjects after lower limb orthopedic surgery. However, the adverse event of surgical site infection can occur equally with upper limb and lower limb surgery because both involve a surgical wound. Other adverse events such as falls or increased pain were not investigated in this review because we were limited by the lack of detail provided in some studies. Most of the trials had small numbers of participants, thus making it difficult to generalize the results to the general subject population.

Conclusions

Aquatic physical therapy can be used as an adjunct to, or instead of, land-based physical therapy to enhance motion in early stages after orthopedic surgery, particularly for rotator cuff repair, TKR, THR, and post-ACL reconstruction. Early aquatic physical therapy does not increase the risk of wound-related adverse events compared with land-based therapy and can result in improved measures of activity. No differences between aquatic and land-based physical therapy were found for pain, edema, strength, ROM, or QOL in the early postoperative period after orthopedic surgery.

Supplier

a. The Cochrane IMS. Available at: http//ims.cochrane.org/revman.

Keywords

Hydrotherapy; Meta-analysis; Orthopedic surgery; Rehabilitation; Review, systematic

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Appendix 1. Search Strategy

Database: MEDLINE

Example of search used (in this case MEDLINE). Searches were optimized by using synonyms for "orthopedic surgery" and using the terms used in previous systematic reviews for the intervention ("aquatic physiotherapy").

1. "Hydrotherapy" OR "Aquatic therapy"
2. (MH "Hydrotherapy") OR "Hydrotherapy" OR (MH "Aquatic Exercises")
3. (MH "Aquatic Exercises") OR "Aquatic Exercise"
4. "Water exercise"
5. "Hot tub"
6. (MH "Balneology") OR "Balneology" OR (MH "Bathing and Baths")
7. (MH "Swimming") OR "Swimming"
8. (MH "Rehabilitation") OR "rehabilitation"
9. (MH "Orthopedics") OR "orthopedic"
10. "Orthopedic Surgery"
11. (MH "Inpatients") OR "inpatient"
12. "Subacute"
13. (MH "Arthroplasty") OR "Arthroplasty" OR (MH "Arthroplasty, Knee, Unicompartmental") OR (MH "Arthroplasty, Reverse Total, Shoulder") OR (MH "Arthroplasty, Replacement, Shoulder") OR (MH "Arthroplasty, Replacement, Knee") OR (MH "Arthroplasty, Replacement, Hip") OR (MH "Arthroplasty, Replacement, Elbow") OR (MH "Arthroplasty, Replacement, Ankle") OR (MH "Arthroplasty, Replacement")
14. "Replacement"

15. "Postsurgical"
16. "Allogenic"
17. S8 or S9 or S10 or S11 or S12 or S13 or S14 or S15 or S16
18. S1 or S2 or S3 or S4 or S5 or S6 or S7
19. S17 and S18

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