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Effectiveness of aquatic exercise for musculoskeletal conditions: A meta-analysis

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ABSTRACT

Objective: To investigate the effectiveness of aquatic exercise in the management of musculoskeletal conditions.

Data Sources: A systematic review was conducted using Ovid MEDLINE, CINAHL, EMBASE, and The Cochrane Central Register of Controlled Trials from earliest record to May 2013.

Study Selection: Randomized controlled trials (RCTs) and quasi-randomized controlled trials evaluating aquatic exercise for adults with musculoskeletal conditions compared to no exercise or land-based exercise. Outcomes of interest were pain, physical function and quality of life. The electronic search identified 1199 potential studies. Of these, 1136 studies were excluded based on title and abstract. A further 36 studies were excluded after full text review and the remaining 26 studies were included in this review.

Data Extraction: Two reviewers independently extracted demographic data and intervention characteristics from included trials. Outcome data including mean scores and SDs were also extracted.

Data Synthesis: The Physiotherapy Evidence Database (PEDro) scale identified 20 studies with high methodological quality (PEDro score $\geq$6). Compared to no exercise, aquatic exercise achieved moderate improvements in pain (SMD -0.37, 95% CI -0.56 to -0.18), physical function (SMD 0.32, 95% CI 0.13 to 0.51) and quality of life (SMD 0.39, 95% CI 0.06 to 0.73). No significant differences were observed between the effects of aquatic and land-based exercise on pain (SMD -0.11, 95% CI -0.27 to 0.04), physical function (SMD -0.03, 95% CI -0.19 to 0.12) or quality of life (SMD -0.10, 95% CI -0.29 to 0.09).

Conclusion: The evidence suggests that aquatic exercise has moderate beneficial effects on pain, physical function and quality of life in adults with musculoskeletal conditions. These benefits appear comparable across conditions and with those achieved with land-based exercise. Further research is needed to understand the characteristics of aquatic exercise programs that provide the most benefit.

Key Words: Aquatic exercise; Arthritis; Land-based exercise; Musculoskeletal; Osteoarthritis; Randomized controlled trial.

ABBREVIATIONS

RCT – Randomized controlled trial

WHO – World Health Organization

PEDro – Physiotherapy Evidence Database

SMD – Standardized mean difference

CI – Confidence interval

Musculoskeletal conditions are widespread and are among the world's leading causes of chronic pain, disability and reduced health-related quality of life(1). A recent report on global burden of disease highlighted that musculoskeletal conditions account for 7% of total disability adjusted life years, with low back pain accounting for nearly half, and osteoarthritis accounting for almost 10% of this burden(2). Musculoskeletal conditions are also the most common causes for utilizing healthcare resources(3). This burden, reflected by endorsement of the Bone and Joint Decade 2000–2010 by the United Nations and WHO, is predicted to rise due to the ageing population(4). As such, identifying and promoting effective management strategies for these conditions has been flagged as a public health priority(5).

There is a growing body of evidence that suggests aquatic exercise can decrease the disease burden of musculoskeletal conditions(6-9). The benefits of aquatic exercise arise from the physiological effects of immersion and the hydrodynamic principles of exercise in the aquatic environment(10). Buoyancy decreases compressive weight-bearing stresses on joints and allows functional exercise with lessened gravitational load, improving both strength and range of movement(11). Additionally, immersion in thermo neutral water (34 degrees Celsius) decreases sympathetic nervous system activity, which in combination with the compressive effects of hydrostatic pressure, can reduce swelling and the perception of pain in people with musculoskeletal conditions(10). The aquatic environment can allow higher-intensity exercises to be undertaken, with lower cardiovascular stress than is possible on land(12).

Despite the increasing number of RCTs being undertaken, the most recent Cochrane systematic review published in 2007, limited to osteoarthritis studies, concluded that there remains a lack of high-quality studies in this area(13). The meta-analysis included data from six RCTs and identified that aquatic exercise had a small-to-moderate short term effect on pain, function and quality of life compared to no intervention(13). A more recent meta-analysis published in 2011 focused only on function, mobility and pooled health outcomes in people with osteoarthritis or rheumatoid arthritis(8). This review included 10 RCTs and concluded that aquatic exercise had comparable effects to land-based exercise. This review again highlighted the variability in methodological quality of included studies, hindering the identification of true differences between the two modes of exercise. Reviews completed on the effects of aquatic exercise for people with fibromyalgia(6, 14) and low-back pain(7) have also reported positive impacts with aquatic exercise but were cautious in their conclusions due to variable study quality.

Whilst there is evidence that aquatic exercise is an effective strategy in the management of a number of musculoskeletal conditions, the relative benefits across conditions has not been reported as previous reviews have only focused on individual conditions. Therefore, the aim of this review was to:

1. Systematically examine the effect of aquatic exercise on pain, physical function and quality of life in people with musculoskeletal conditions when compared to both no exercise and land-based exercise; and
2. Investigate the relative effectiveness of aquatic exercise for individual musculoskeletal conditions including osteoarthritis, rheumatoid arthritis, fibromyalgia, low back pain and osteoporosis.

METHODS

Literature search

A systematic search of literature was conducted up until May 2013. Ovid MEDLINE, CINAHL, EMBASE and The Cochrane Central Register of Controlled Trials (April 2013) were searched to identify published research. A sensitive search strategy was developed using medical subject heading (MESH) search terms and keywords (Appendix 1), and was translated for each database as appropriate. The references of included studies were also reviewed for further relevant literature.

Eligibility criteria

Study selection. Two reviewers (ALB and JT) independently screened and excluded studies based on title and abstracts. For articles not excluded by this process, full text was obtained and assessed independently by both reviewers against the inclusion and exclusion criteria. If a decision could not be reached between the two reviewers a third reviewer (RTM) was called upon for the final decision.

Types of studies and participants. Studies were included if they were conducted as a RCT or quasi-randomized controlled trial. Participants had to be diagnosed with at least one musculoskeletal condition using accepted arthritis and musculoskeletal diagnostic criteria. Studies with participants less than 18 years of age or who had recently had surgery (e.g. arthoplasty or spinal surgery) were excluded.

Interventions. Studies must have included one group that participated in aquatic exercise and a comparison group that participated in no exercise (including non-active activities such as education) or land-based exercise. Aquatic exercise interventions were defined as any type of endurance, flexibility, strength, resistance or aerobic exercise conducted in a pool. Other hydrotherapy methods such as turbulent spa therapy and balneotherapy (immersion in mineralized water) were excluded because these approaches do not usually include an active exercise component.

Outcomes. Outcomes of interest were pain, physical function and quality of life. To be included in this review, studies must have reported outcome measures known to be responsive for measuring change in pain, physical function or quality of life in people with musculoskeletal conditions. When two outcome measures were available for the same outcome only one was included in the meta-analysis. Generic (non-disease or condition specific) outcome measures were prioritized for inclusion in the meta-analysis followed by disease specific measures based on priority lists defined by prior Cochrane systematic reviews(13). Outcome measures were also required to be scored on a 0-100 scale or could be converted to this. The list of outcome measures which met the inclusion criteria are listed in Table 1 in descending order of priority.

Methodological quality assessment

All included studies were assessed for methodological quality independently by two reviewers (JT and ALB) using the PEDro scale(15). This scale rates 11 aspects of methodological quality of RCTs as being either absent or present (Appendix 2). As the first item (eligibility criteria) is not scored, the total score ranges from 0 to 10. Studies that obtain a score of <6 points are considered as low quality, while those with a score ≥6 points are considered high quality(16). A third reviewer (RTM) was called if consensus could not be reached.

Data extraction

Two reviewers (ALB and JT) independently extracted data for the included studies. Demographic data (age, sex, and musculoskeletal condition) and intervention characteristics (exercise components, duration, and frequency) were extracted from included trials. Outcome data including mean scores, SDs, and sample sizes were also extracted for two time points—baseline (pre-intervention) and first follow-up (post-intervention) assessment. When necessary, the SD was approximated by dividing the inter-quartile range by 1.35, and medians were used as best estimates of means.

Statistical Analysis

A meta-analysis was conducted using pooled data and described as standardized mean difference (SMD) and 95% CIs. This method is useful for comparing data collected using different scales (17). Heterogeneity between trials was assessed using the I^2 statistic(18). Statistical heterogeneity was considered substantial if I^2 was greater than 50% (heterogeneous), and in this event a random effects model was applied; otherwise a fixed-effects model was used (17). Outcome data was excluded from the meta-analysis if there were significant differences in baseline scores of the outcome of interest to ensure SMD in post-intervention scores were not confounded. A SMD of less than 0.2 was considered a small effect, between 0.2 and 0.8 a moderate effect and greater than 0.8 a large effect(19). Scale directions were aligned by adding negative values where required. A separate meta-analysis was run for each outcome and comparator options. For each meta-analysis, a secondary analysis was conducted that excluded studies of low methodological quality

(PEDro score < 6) so that estimates of effect could be established that avoided distortion probable from inclusion of findings from low quality studies. All meta-analyses were performed using Review Manager (RevMan5.2) software.

RESULTS

Search yield

The electronic search identified 1199 potential studies for screening of eligibility after duplicate studies were removed. Of these, 1136 studies were excluded based on title and abstract. The full text was obtained for the remaining 63 studies. Based on the reviewer's decisions, 36 studies were excluded after full text review as they did not meet inclusion criteria (Appendix 3) and 26 studies were included in the review(20-45) (Figure 1).

Description of included studies

The 26 included studies consisted of 24 randomised controlled studies (21, 22, 24-45) and two quasi-randomised controlled trials(20, 23) in osteoarthritis, rheumatoid arthritis, fibromyalgia, low back pain and osteoporosis populations. The majority of studies (16; 62%)(21, 22, 26-29, 32-34, 36-39, 43-45) were conducted in people with osteoarthritis. Eighteen studies(20-22, 26, 27, 29, 31-36, 38-41, 43, 44) compared aquatic exercise to no exercise; 15(20, 23-28, 30, 33, 34, 38, 39, 42, 44, 45) to some form of land-based exercise and seven studies(20, 26, 27, 33, 34, 39, 44) included both no exercise and land-based exercise comparisons. Participants were typically older with 16 studies(20-22, 26-29, 31-34, 36, 38, 39, 43, 44) including participants with a mean age of over 60 years (Table 2).

Methodological quality

Methodological quality was independently assessed by two reviewers (JT and ALB). A third reviewer (RTM) was required to assess the methodological quality for five studies, as the first two reviewers could not reach a consensus. The median score for methodological quality using the PEDro scale was 6 out of 10 (range 4-8) indicating studies were of high quality. Twenty studies(20, 22, 23, 25-30, 32-37, 41-45) were assessed as being high quality (PEDro score ≥6) (Table 2). Common methodological limitations identified across studies included omission of reporting if analysis was performed on an intention to treat basis and whether allocation was concealed.

Aquatic exercise program characteristics

Aquatic exercise programs varied substantially across the included studies in terms of total intervention duration (3-52 weeks), frequency (1-7 times per week) and class duration (30-60 minutes) (Table 2). Variability was also observed for the types of exercises included in programs; however it was common for programs to include warm-up, strength, stretching, range of motion, aerobic and cool-down exercises.

Effects of interventions

The majority of studies reported on pain (25; 96%) and physical function outcomes (24; 92%) (Table 2). For physical function and quality of life outcomes, positive scores indicated improved health, whereas for pain outcomes, negative scores indicated improved health (i.e. a reduction in pain). All studies reported SD values therefore no approximations of these values were required.

Pain

Fifteen studies(21, 22, 26, 27, 29-33, 36, 38, 40, 41, 43, 44) were included in the meta-analysis of pain outcomes for aquatic compared to no exercise. There was significant heterogeneity detected for studies (I^2=53%). When a random-effects analysis was applied, compared to no exercise, aquatic exercise achieved a moderate reduction in pain (SMD -0.37, 95% CI -0.56 to -0.18). Effects were comparable across osteoarthritis, rheumatoid arthritis, fibromyalgia and low back pain populations (test for sub-group differences p=0.07) (Figure 2a). When the meta-analysis was repeated excluding low methodological quality studies (21, 31, 38, 40) there was no appreciable difference in the effect on pain (SMD -0.33, 95% CI -0.53 to -0.13).

Ten studies(23-25, 27, 28, 30, 33, 37, 44, 45) were included in the meta-analysis of pain outcomes for aquatic compared to land-based exercise. There was no significant heterogeneity detected for studies (I^2=50%). When a fixed-effects analysis was applied, compared to land-based exercise, aquatic exercise achieved a small non-significant reduction in pain (SMD -0.11, 95% CI -0.27 to 0.04). Effects on pain were comparable across osteoarthritis, rheumatoid arthritis, fibromyalgia and low-back pain populations (test for sub-group differences (p=0.08) (Figure 2b). When the meta-analysis was repeated excluding low methodological quality studies(24), no appreciable difference was found (SMD -0.08, 95% CI -0.27 to 0.09).

Physical function

Fourteen studies(20, 22, 26, 27, 29, 30, 32, 35, 36, 38, 40, 41, 43, 44) were included in the meta-analysis of physical function outcomes for aquatic compared to no exercise. Significant heterogeneity was detected for these studies (I^2=53%). When a random-effects analysis was applied, compared to non-active controls, aquatic exercise achieved a moderate improvement in physical function (SMD 0.32, 95% CI 0.13 to 0.51) and effects were comparable across osteoarthritis, rheumatoid arthritis and fibromyalgia populations. There was some evidence of a difference of effects across the included condition types with the one study conducted in people with osteoporosis favoring the non-active control (test for sub-group differences

P=0.02). No studies were included that reported on physical function outcomes in low back pain population (Figure 3a). When the meta-analysis was repeated excluding low methodological quality studies(38, 40) there was no appreciable difference in the effect on physical function (SMD 0.28, 95% CI 0.09 to 0.42).

Ten studies(20, 23, 25, 27, 28, 30, 34, 39, 42, 44) were included in the meta-analysis of physical function outcomes for aquatic compared to land-based exercise. There was no significant heterogeneity detected for studies (I^2=38%). Applying a fixed-effects analysis, when compared to land-based exercise, aquatic exercise achieved comparable effects on physical function (SMD -0.03, 95% CI -0.19 to 0.12) and this effect was consistent across all populations (test for sub-group differences P=0.10) (Figure 3b). When the meta-analysis was repeated excluding low methodological quality studies(39) there was no appreciable difference in the effect on physical function (SMD -0.04, 95% CI -0.20 to 0.12).

Quality of life

Eleven studies(20, 21, 26, 27, 29, 30, 33, 34, 36, 38, 44) were included in the meta-analysis of quality of life outcomes for aquatic compared to no exercise. Significant heterogeneity was detected for studies (I^2=78%). When a random-effects analysis was applied, aquatic exercise achieved moderate improvements in quality of life compared to non-active controls (SMD 0.39, 95% CI 0.06 to 0.73). There was some evidence of a difference of effects across the included condition types (test for sub-group differences P=0.02). Whilst a moderate improvement in quality of life was observed in studies conducted in osteoarthritis populations, small non-significant effects were observed in the osteoporosis or rheumatoid arthritis populations in favor of the non-active control group (Figure 4a). However, this finding was limited to only one study in each population. When the meta-analysis was repeated excluding low methodological quality studies (21, 38) there was no appreciable difference in the effect.

Seven studies(20, 25, 26, 30, 33, 34, 44) were included in the meta-analysis of quality of life outcomes for aquatic exercise compared to land-based exercise. No significant heterogeneity was detected for studies (I^2=12%). When a fixed-effects model analysis was applied, compared to land-based exercise, aquatic exercise achieved comparable improvements in quality of life (SMD -0.10, 95% CI -0.29 to 0.09). These effects were consistent across osteoarthritis and osteoporosis populations (test for sub-group differences P=0.47). There were no studies that reported on quality of life outcomes that compared aquatic to land-based exercise in fibromyalgia or low-back pain populations. All studies reporting on quality of life were of high methodological quality (Figure 4b).

DISCUSSION

This review provides new evidence that aquatic exercise provides moderate benefits to people with musculoskeletal conditions reflected in reduced pain and improved physical function and quality of life. These results are consistent with prior reviews that focused on individual musculoskeletal conditions in isolation. Improvements in pain and physical function were observed to be mostly consistent across different musculoskeletal conditions. Importantly, these results persisted when low quality studies were removed from analysis.

Compared to land-based exercise, aquatic exercise achieved equivalent improvements in all outcomes. This indicates that patients can choose the exercise mode that appeals most to them. This is an important finding as provision of patient choice in treatment interventions is known to improve patient outcomes(46) and participation, which is a critical factor to intervention effectiveness. Even if an intervention is effective, if it is not accepted by the target population it is of little benefit. A review of exercise participation among people with osteoarthritis(47) found that poor participation is the most compelling explanation for the declining impact of the benefits of exercise over time. Several of the studies in this review observed higher participation levels in aquatic exercise compared to land-based exercise groups (26, 34, 37). Future studies should aim to explore patient preferences for aquatic exercise compared to land-based exercise and the relative long-terms effects of aquatic exercise.

Musculoskeletal conditions are not mutually exclusive(3). The pathophysiology of each disorder differs between each condition(3). Despite this difference, musculoskeletal conditions share a range of associated symptoms including pain, fatigue, and difficulties with activities of daily living(3). Prior reviews have sought to establish the effectiveness of aquatic exercise with an individual focus on one musculoskeletal condition(7, 8, 13, 14), failing to find the potential differential effects of aquatic exercise across multiple musculoskeletal conditions. This is the first meta-analysis conducted across different musculoskeletal conditions. Our results have provided precise pooled estimates of treatment effects of aquatic exercise across multiple musculoskeletal conditions, including osteoarthritis; rheumatoid arthritis; fibromyalgia; low back pain; and osteoporosis. Meta-analysis results showed benefits were mostly consistent across condition types. Improvements in pain were consistent across the different musculoskeletal conditions; however the reduction in pain for rheumatoid and low back pain populations was non-significant. This may be an artifact of only one study being included for each of these populations and so meta-analysis of effects for these condition sub-groups could not be performed. Improvement in physical function was consistent across osteoarthritis, rheumatoid arthritis and fibromyalgia populations in studies that compared aquatic exercise to no exercise. However, when compared to land-based exercise, this effect was lost in the osteoarthritis and fibromyalgia populations. No improvements were observed for physical function in the osteoporosis population when compared to either no exercise or land-based exercise. It is important to note that there were a limited number of studies in low-back pain, rheumatoid arthritis, osteoporosis and fibromyalgia populations and so the differential effects noted across conditions must be interpreted with caution. Further studies and analysis are required to more accurately determine differential effects across different musculoskeletal conditions.

Data on quality of life was rarely reported in studies despite being an important outcome for people with musculoskeletal conditions. People participating in warm water exercise often report an enhanced sense of well-being. Impacts on quality of life were investigated in osteoarthritis, rheumatoid arthritis and osteoporosis populations, and positive effects in the aquatic exercise group were reported for only osteoarthritis studies. The effect of aquatic exercise on quality of life for other musculoskeletal conditions (fibromyalgia and low back pain) remains uncertain and needs further investigation. Quality of life outcomes should be included in future studies investigating the effect of aquatic exercise for people with musculoskeletal conditions.

There was considerable variability between the aquatic exercise programs used in each study. Disappointingly, many studies supplied limited details on the types of exercise, dose and intensity included in the aquatic exercise intervention. This made comparisons between studies and identification of characteristics of the most beneficial programs difficult. Based on this review, further research is required to investigate the characteristics of aquatic exercise programs that provide the most beneficial results.

Study Limitations

Only RCTs published in English were included, therefore potentially relevant high quality studies with different designs or in other languages may have been excluded. In addition, searches were limited to published studies only. As there is a tendency for editors to publish studies with positive findings, this review may be subject to publication bias. We found a high heterogeneity and wide CIs of most effect sizes, and variability in study quality and exercise interventions (frequency and types of exercise) that may have contributed random error to outcomes. Of note, the aim of this literature review was to explore the benefits of aquatic exercise in several different musculoskeletal clinical groups in the peer review literature. As such, this review was undertaken with a broad exploratory focus and pooled studies of different musculoskeletal conditions with different pathophysiology. However we avoided this issue by also looking at different sub-group effects. This potential limitation needs to be acknowledged when considering the review findings.

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CONCLUSIONS

Overall, the studies included in this review were of high quality and demonstrate that aquatic exercise can have positive effects on pain, physical function and quality of life for adults with musculoskeletal conditions. However, there is further need for large scale trials of sufficient duration and an adequate follow-up period to validate the long-term effects of aquatic exercise. In addition, future trials need to examine different modes, frequency, intensity and participation in aquatic exercise programs so the characteristics of programs that achieve maximum benefits are well understood.

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FIGURE LEGENDS

Figure 1: Flow chart of study exclusion process.

Figure 2: Meta-analysis of pain outcomes

(a) Aquatic exercise vs. No exercise

(b) Aquatic exercise vs. Land-based exercise

Figure 3: Meta-analysis of physical function outcomes

(a) Aquatic exercise vs. No exercise

(b) Aquatic exercise vs. Land-based exercise

Figure 4: Meta-analysis of quality of life outcomes

(a) Aquatic exercise vs. No exercise

(b) Aquatic exercise vs. Land-based exercise

Appendix 1: Search Strategy

In MEDLINE the following subject specific search strategy was applied:

#1: hydrotherapy

#2: aquatic therapy

#3: aquatic exercise

#4: arthritis

#5: arthritis, rheumatoid

#6: osteoarthritis

#7: fibromyalgia

#8: low back pain

#9: osteoporosis

#10: musculoskeletal diseases

#11: 1 or 2 or 3

#12: 4 or 5 or 6 or 7 or 8 or 9 or 10

#13: 11 and 12

Appendix 2: PEDro scale items

1. Eligibility criteria
2. Random allocation
3. Concealed allocation
4. Baseline comparability
5. Blind subjects
6. Blind therapists
7. Blind assessors
8. Adequate follow-up
9. Intention-to-treat analysis
10. Between-group comparisons
11. Point estimates and variability

Appendix 3: List of excluded studies after reading full text

Study	**Reason for exclusion**
Ahern et al. (1995)	Not an RCT
Altan et al. (2004)	Comparison group inappropriate
Arnold et al. (2010)	Outcomes/outcome measures inappropriate
Ashina et al. (2010)	Outcomes/outcome measures inappropriate
Baena-Beato et al. (2013)	Not an RCT
Batterham et al. (2011)	Not an RCT
Bartels et al. (2009)	Not an RCT
Brosseau et al. (2002)	Not an RCT
Brosseau et al. (2010)	Not an RCT
Cadmus et al. (2010)	Outcomes/outcome measures inappropriate
Cuesta-Vargas et al. (2011)	Intervention was inappropriate
Cuesta-Vargas et al. (2011)	Intervention was inappropriate
Dagfinrud et al. (2009)	Not an RCT
Escalante et al. (2010)	Not an RCT
French et al. (2013)	Intervention was inappropriate
Giaquinto et al. (2010)	Wrong population (recovering after TKA)
Green et al. (1993)	Outcome measures inappropriate
Guillemin et al. (1994)	Intervention was inappropriate
Gusi et al. (2006)	Outcomes/outcome measures inappropriate
Gusi et al. (2008)	Outcomes/outcome measures inappropriate
Harmer et al. (2009)	Wrong population (recovering after total knee replacement)
Kelley et al. (2008)	Not an RCT

Langhorst et al. (2009)	Not an RCT
Lin et al. (2004)	Not an RCT
Mannerkorpi et al. (2002)	Not an RCT
Matsumoto et al. (2011)	Intervention was inappropriate
Mcllveen et al. (1998)	Outcomes/outcome measures inappropriate
McVeigh et al. (2008)	Not an RCT
Mobily et al. (2001)	Not an RCT
Perraton et al. (2009)	Not an RCT
Sjogren et al. (1997)	Not an RCT
Tilden et al. (2010)	Not an RCT
Van Tubergen et al. (2001)	Intervention was inappropriate
Verhagen et al. (2008)	Not an RCT
Waller et al. (2009)	Not an RCT
Yurtkuran et al. (2006)	Intervention was inappropriate

Table 1: Outcome measures eligible to be included in the meta-analysis

Pain	VAS-Pain, HAQ-Pain, SF-36-Pain, SF-12-Pain, EQ-5D-Pain, BPI, Functional Capacity Evaluation-Pain, WOMAC-Pain, AIMS-2-Pain, KOOS-Pain, FIQ-Pain
Physical Function	HAQ-Function, DRI, SF-36-Function, SF-12-Physical function, EQ-5D-Mobility, Functional Capacity Evaluation-ADLs, FAP, SPF Scale, AAP, WOMAC-Function, AIMS-2-Physical Activity, KOOS-ADLs , ASEQ-Function, OP functional disability questionnaire-Functional abilities domain, FIQ-Function
Quality of life (QoL)	EQ-5D, SF-36 and SF-12-Physical health), AQoL, PQOL, QWB (Quality of Well-Being Scale), GSI (Global Self-Rating Index), AIMS-2-Affect, Arthritis QoL scale-Total score, KOOS-QoL

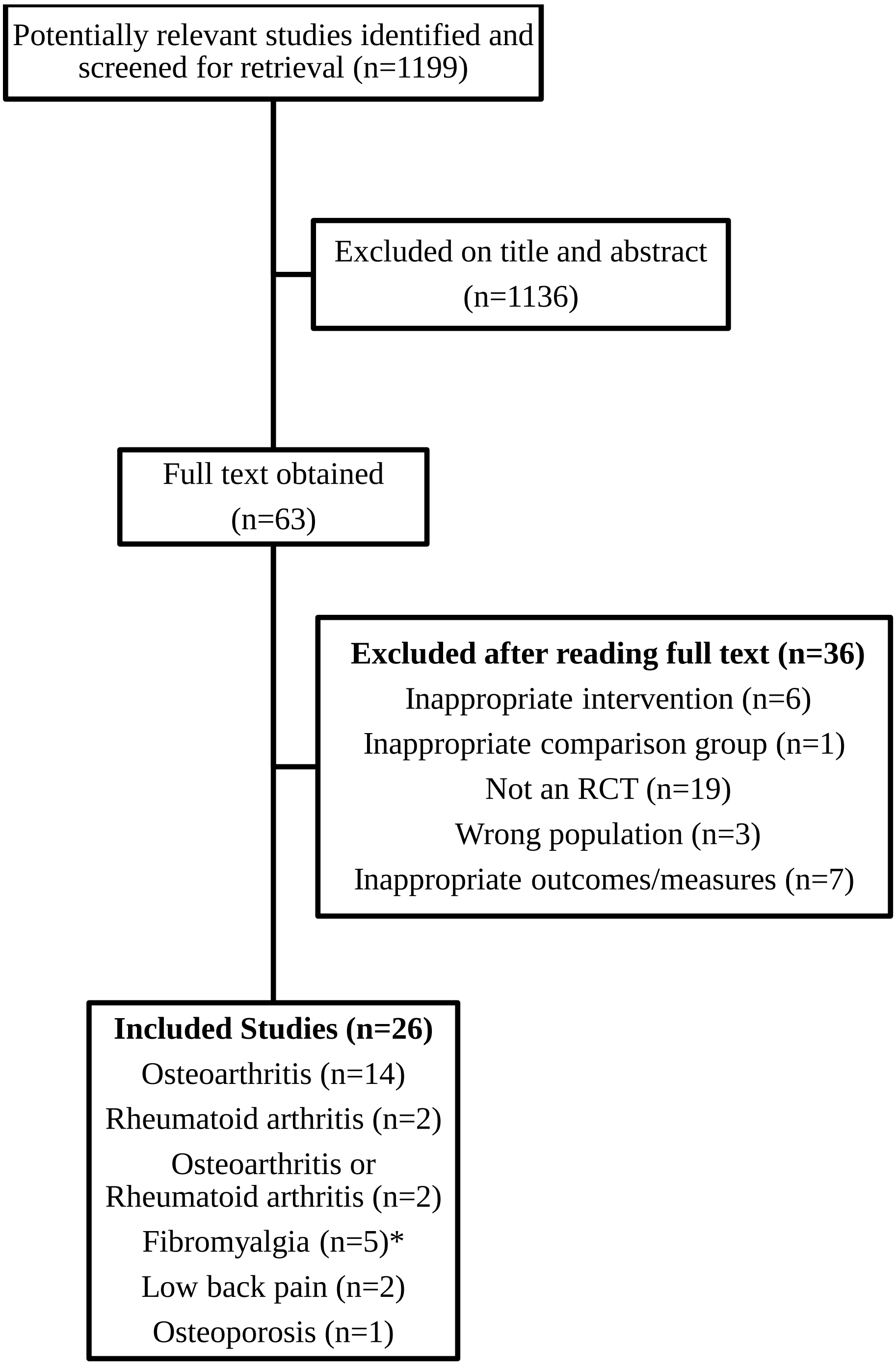
VAS=Visual Analogue Scale; HAQ= Health Assessment Questionnaire; SF-36=36-Item Short Form Health Survey; SF-12= 12-Item Short Form Health Survey; EQ-5D=European Quality of Life-5 Dimensions scale; BPI=Brief Pain Inventory; WOMAC=Western Ontario and McMaster Universities Osteoarthritis Index; AIMS-2=Arthritis Impact Measurement Scale 2; KOOS=Knee Injury and Osteoarthritis Outcome Score; FIQ=Fibromyalgia Impact Questionnaire; DRI=Disability Rating Index; ADLs=Activities of Daily Living FAP=Functional Ambulation Performance; SPF=Summary Physical Function; AAP=Adelaide Activities' Profile; ASEQ= Arthritis Self-Efficacy Questionnaire; PQOL= Perceived Quality Of Life Scale; QWB=Quality of Well-Being Scale); GSI=Global Self-Rating Index

Table 2: Characteristics of included studies

	Diagnosis	Comparator		Number of subjects randomised			Age, Mean (SD)			Outcomes assessed			Duration of intervention (weeks)	Sessions/ week	PEDro score (0-10)
		LB	C	AE	LB	C	AE	LB	C	Pain	PF	QoL			
Arnold et al. (2008)	OP	✓	✓	21	20	20	68.6 (5.4)	69.1 (6.3)	67.7 (6.3)	×	✓	✓	20	50 min x 3	6
Belza et al. (2002)	OA		✓	125		20	65.98 (5.94)		66.09 (6.16)	✓	✓	✓	20	60 min x 1-7	5
Cochrane et al. (2005)	OA lower limbs		✓	153		52	69.86 (6.82)		69.63 (6.26)	✓	✓	✓	52	60 min x 2	7
Dundar et al. (2009)	LBP	✓		32	33	4	35.3 (7.8)	34.8 (8.3)		✓	✓	✓	4	60 min x 5	6
Evcik et al. (2008)	FM	✓		31	30	5	43.8 (7.7)	42.8 (7.6)		✓	✓	×	5	60 min x 3	5
Eversden et al. (2007)	RA	✓		57	58	6	55.2 (13.3)	56.1 (11.9)		✓	✓	✓	6	30 min x 1	7
Foley et al. (2003)	OA hip/ knee	✓	✓	35	35	6	73.0 (8.2)	69.8 (9.2)	69.8 (9.0)	✓	✓	✓	6	30 min x 3	7
Fransen et al. (2007)	OA hip/ knee	✓	✓	55	56	12	70.0 (6.3)	70.8 (6.3)	69.6 (6.1)	✓	✓	✓	12	60 min x 2	8
Gill et al. (2009)	OA and RA	✓		42	44	6	71.6 (8.9)	69.2 (10.5)		✓	✓	×	6	60 min x 2	6
Hale et al. (2012)	OA		✓	23		12	73.6 (1.5)		75.7 (1.1)	✓	✓	×	12	60 min x 2	8
Hall et al. (1996)	RA	✓		35	34	4	55.8 (12.5)	59.5 (11.0)		✓	×	✓	4	30 min x 2	6
Han et al. (2011)	LBP		✓	9		10	61.2 (3.3)		60.8 (5.0)	✓	×	×	10	50 min x 5	5
Hinman et al. (2007)	OA hip/ knee		✓	36		20	63.3 (9.5)		61.5 (7.8)	✓	✓	✓	20	45-60 min x 2	8
Lim et al. (2010)	Obesity/ OA knee	✓	✓	26	25	8	65.7 (8.9)	63.3 (5.3)	63.3 (5.3)	✓	✓	✓	8	40 min x 3	7
Lund et al. (2008)	OA knee	✓	✓	27	25	8	65 (12.6)	68 (9.5)	70 (9.9)	✓	✓	✓	8	50 min x 2	6
Munguia-Izquierdo et al. (2008)	FM		✓	35		16	50 (7)		46 (8)	✓	✓	×	16	60 min x 3	8
Patrick et al. (2001)	OA hip/		✓	125		20	65.7		66.1	✓	✓	✓	20	45-60	6

	knee													min x 2-7	
Silva et al. (2008)	OA knee	✓		32	32	18	59 (7.60)	59 (6.08)		✓	✓	✗	18	50 min x 3	7
Stener-Victorin et al. (2004)	OA hip		✓	15		5	70.3		65.5	✓	✓	✓	5	30 min x 2	4
Suomi and Collier (2003)	OA and RA	✓	✓	11	11	8	68.0 (6.8)	64.2 (3.3)	68.3 (6.2)	✓	✓	✗	8	45 min x 2	4
Tomas-Carus et al. (2007)	FM		✓	18		12	51 (10)		51 (9)	✓	✓	✓	12	60 min x 3	5
Tomas-Carus et al. (2009)	FM		✓	17		32	50.7 (10.6)		50.9 (6.7)	✓	✓	✗	32	60 min x 3	7
Vitorino et al. (2006)	FM	✓		25	25	3	48.9 (9.2)	46.6 (8.4)		✓	✓	✓	3	60 min x 3	7
Wang et al. (2007)	OA hip/ knee		✓	21		12	69.3 (13.3)		62.7 (10.7)	✓	✓	✗	12	60 min x 3	6
Wang et al. (2011)	OA knee	✓	✓	28	28	12	66.7 (5.6)	68.3 (6.4)	67.9 (5.9)	✓	✓	✓	12	60 min x 3	7
Wyatt et al. (2001)	OA knee	✓		23	23	6	-	-		✓	✓	✗	6	NR x 3	6

LB=Land based exercise, C=Non-active control, AE=Aquatic exercise, PF=Physical function, QoL=Quality of life, SD=Standard deviation, OA=Osteoarthritis, RA=Rheumatoid arthritis, FM=Fibromyalgia, LBP=Low back pain, OP=Osteoporosis, - = Not reported in the publication, NR=Not Reported

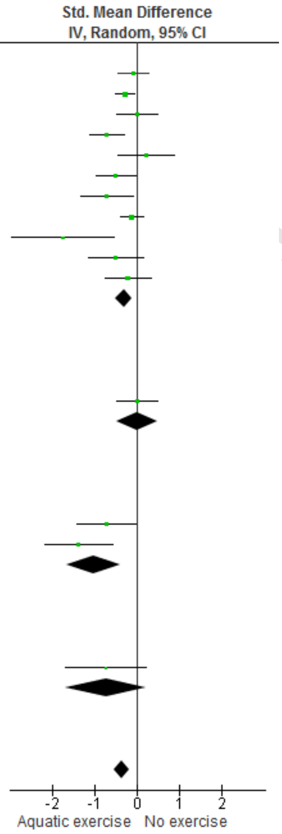


*****One study consisted of 2 publications reporting on different outcome measures and was recorded as one study in this review.

Figure 2: Meta-analysis of pain outcomes

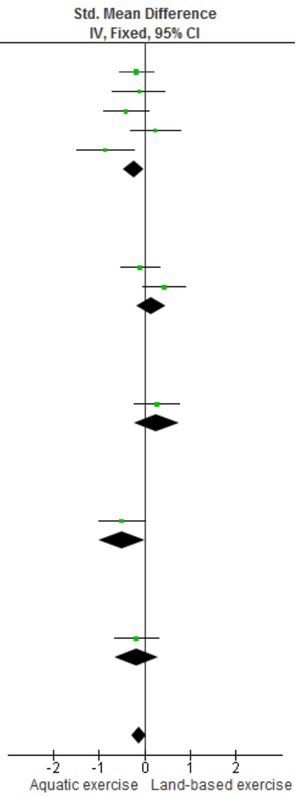
(a) Aquatic exercise vs. No exercise

Study or Subgroup	Aquatic exercise Mean	SD	Total	No exercise Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
1.1.1 Osteoarthritis								
Belza 2002	46.67	28.67	36	48.67	20.67	117	9.2%	-0.09 [-0.46, 0.29]
Cochrane 2005	-46.64	22.38	152	-40.74	20.49	158	12.1%	-0.27 [-0.50, -0.05]
Foley 2003	50	20	34	50	15	32	7.4%	0.00 [-0.48, 0.48]
Fransen 2007	27.3	18.7	55	40	16.2	41	8.5%	-0.71 [-1.13, -0.30]
Hale 2012	39	19.6	20	35.5	9.6	15	5.0%	0.21 [-0.46, 0.88]
Hinnman 2006	40	20	36	50	20	35	7.5%	-0.49 [-0.97, -0.02]
Lim 2010	32.7	16.7	24	45.5	18.8	20	5.7%	-0.71 [-1.32, -0.10]
Patrick 2001	46.1	24.57	98	48.73	20.63	117	11.3%	-0.12 [-0.39, 0.15]
Stener-Victorin 2004	7.5	5.5	9	41.5	27.4	7	2.0%	-1.75 [-2.95, -0.54]
Wang 2007	43.5	18.6	20	54.9	25.2	18	5.3%	-0.51 [-1.16, 0.14]
Wang 2011	-72	18	26	-68	18	26	6.5%	-0.22 [-0.76, 0.33]
Subtotal (95% CI)			**510**			**586**	**80.6%**	**-0.31 [-0.50, -0.13]**
Heterogeneity: Tau² = 0.04; Chi² = 18.79, df = 10 (P = 0.04); I² = 47%								
Test for overall effect: Z = 3.28 (P = 0.001)								
1.1.2 Rheumatoid Arthritis								
Hall 1996	48	27	35	48	19	35	7.6%	0.00 [-0.47, 0.47]
Subtotal (95% CI)			**35**			**35**	**7.6%**	**0.00 [-0.47, 0.47]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 0.00 (P = 1.00)								
1.1.3 Fibromyalgia								
Tomas-Carus 2007	-44	23	17	-28	20	17	4.8%	-0.72 [-1.42, -0.03]
Tomas-Carus 2009	-51.7	13.1	15	-27.1	20.9	15	3.9%	-1.37 [-2.18, -0.57]
Subtotal (95% CI)			**32**			**32**	**8.7%**	**-1.02 [-1.65, -0.38]**
Heterogeneity: Tau² = 0.06; Chi² = 1.42, df = 1 (P = 0.23); I² = 29%								
Test for overall effect: Z = 3.15 (P = 0.002)								
1.1.4 Low Back Pain								
Han 2011	31.2	23.2	9	58.9	44.2	10	3.1%	-0.74 [-1.68, 0.20]
Subtotal (95% CI)			**9**			**10**	**3.1%**	**-0.74 [-1.68, 0.20]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 1.54 (P = 0.12)								
Total (95% CI)			**586**			**663**	**100.0%**	**-0.37 [-0.56, -0.18]**
Heterogeneity: Tau² = 0.06; Chi² = 29.53, df = 14 (P = 0.009); I² = 53%								
Test for overall effect: Z = 3.89 (P < 0.0001)								
Test for subgroup differences: Chi² = 7.19, df = 3 (P = 0.07), I² = 58.3%								



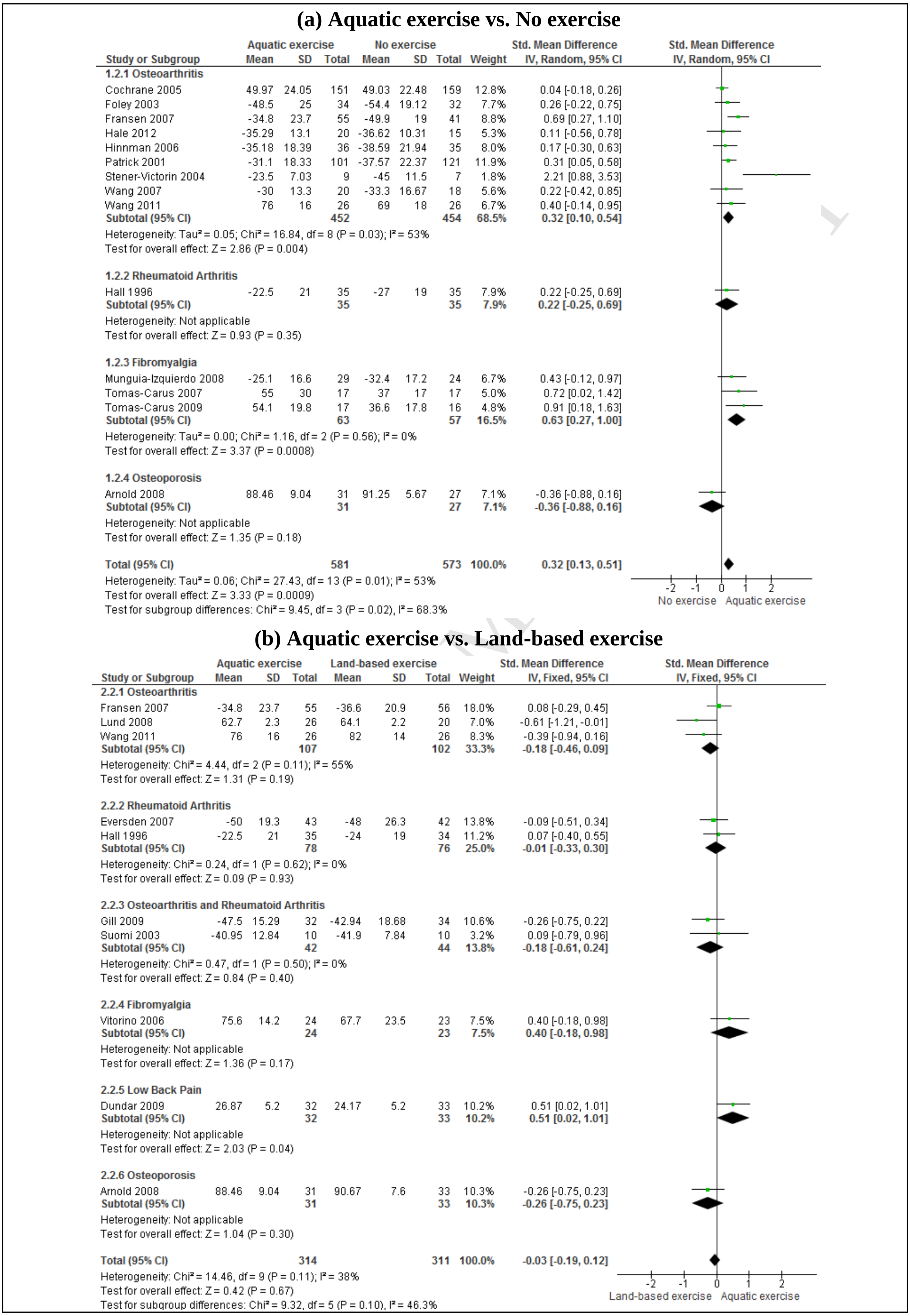
(b) Aquatic exercise vs. Land-based exercise

Study or Subgroup	Aquatic exercise Mean	SD	Total	Land-based exercise Mean	SD	Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
2.1.1 Osteoarthritis								
Fransen 2007	27.3	18.7	55	30.7	18.9	56	17.0%	-0.18 [-0.55, 0.19]
Lim 2010	32.7	16.7	24	34.6	13	22	7.0%	-0.12 [-0.70, 0.46]
Silva 2008	26.7	23.1	32	37.3	27.5	32	9.6%	-0.41 [-0.91, 0.08]
Wang 2011	-72	18	26	-76	15	26	7.9%	0.24 [-0.31, 0.78]
Wyatt 2001	24	16	21	38	16	21	5.9%	-0.86 [-1.49, -0.22]
Subtotal (95% CI)			**158**			**157**	**47.5%**	**-0.23 [-0.46, -0.01]**
Heterogeneity: Chi² = 7.31, df = 4 (P = 0.12); I² = 45%								
Test for overall effect: Z = 2.04 (P = 0.04)								
2.1.2 Rheumatoid Arthritis								
Eversden 2007	25.5	22.22	43	27.5	21.85	42	13.1%	-0.09 [-0.52, 0.34]
Hall 1996	48	27	35	38	18	34	10.4%	0.43 [-0.05, 0.91]
Subtotal (95% CI)			**78**			**76**	**23.4%**	**0.14 [-0.18, 0.46]**
Heterogeneity: Chi² = 2.53, df = 1 (P = 0.11); I² = 61%								
Test for overall effect: Z = 0.86 (P = 0.39)								
2.1.3 Osteoarthritis and Rheumatoid Arthritis								
Gill 2009	50.5	14.5	32	46	18.5	34	10.1%	0.27 [-0.22, 0.75]
Subtotal (95% CI)			**32**			**34**	**10.1%**	**0.27 [-0.22, 0.75]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 1.08 (P = 0.28)								
2.1.4 Fibromyalgia								
Evcik 2007	42	16	31	51	19	30	9.1%	-0.51 [-1.02, 0.00]
Subtotal (95% CI)			**31**			**30**	**9.1%**	**-0.51 [-1.02, 0.00]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 1.94 (P = 0.05)								
2.1.5 Low Back Pain								
Dundar 2009	16.8	11.2	32	19	13.3	33	10.0%	-0.18 [-0.66, 0.31]
Subtotal (95% CI)			**32**			**33**	**10.0%**	**-0.18 [-0.66, 0.31]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 0.71 (P = 0.48)								
Total (95% CI)			**331**			**330**	**100.0%**	**-0.11 [-0.27, 0.04]**
Heterogeneity: Chi² = 18.08, df = 9 (P = 0.03); I² = 50%								
Test for overall effect: Z = 1.46 (P = 0.14)								
Test for subgroup differences: Chi² = 8.24, df = 4 (P = 0.08), I² = 51.5%								



Total=number of particpants in the study group

Figure 3: Meta-analysis of physical function outcomes

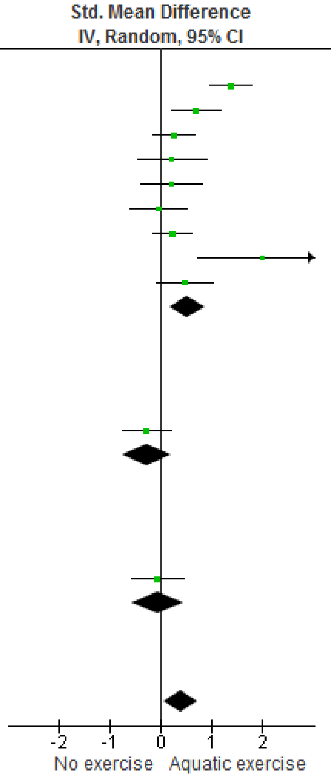


Total=number of particpants in the study group

Figure 4: Meta-analysis of quality of life outcomes

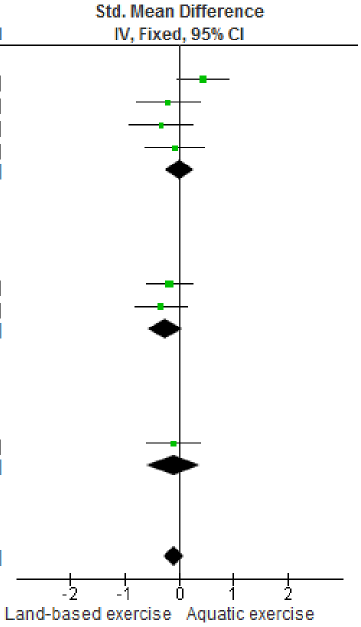
(a) Aquatic exercise vs. No exercise

Study or Subgroup	Aquatic exercise Mean	SD	Total	No exercise Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
1.3.1 Osteoarthritis								
Belza 2002	-13.9	7.5	36	-54.5	33	121	10.4%	1.38 [0.98, 1.78]
Foley 2003	37.1	12.7	35	28.8	11	35	9.7%	0.69 [0.21, 1.17]
Fransen 2007	35.7	9.8	55	33.1	10.6	41	10.4%	0.25 [-0.15, 0.66]
Hale 2012	84.8	17.1	20	81.1	15.1	15	8.2%	0.22 [-0.45, 0.89]
Lim 2010	38.8	7.7	24	36.9	9.6	20	8.8%	0.22 [-0.38, 0.81]
Lund 2008	43	2.4	26	43.1	2.3	24	9.1%	-0.04 [-0.60, 0.51]
Patrick 2001	71	15	36	66.9	18.2	121	10.6%	0.23 [-0.14, 0.61]
Stener-Victorin 2004	-3.7	0.8	9	-30	19	7	4.4%	2.00 [0.73, 3.27]
Wang 2011	73	12	26	67	13	26	9.2%	0.47 [-0.08, 1.02]
Subtotal (95% CI)			**267**			**410**	**80.7%**	**0.53 [0.17, 0.88]**
Heterogeneity: Tau² = 0.21; Chi² = 32.86, df = 8 (P < 0.0001); I² = 76%								
Test for overall effect: Z = 2.90 (P = 0.004)								
1.3.2 Rheumatoid arthritis								
Hall 1996	-33	16	35	-29	13	35	9.8%	-0.27 [-0.74, 0.20]
Subtotal (95% CI)			**35**			**35**	**9.8%**	**-0.27 [-0.74, 0.20]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 1.13 (P = 0.26)								
1.3.3 Osteoporosis								
Arnold 2008	89.29	11.71	31	90	10.43	27	9.5%	-0.06 [-0.58, 0.45]
Subtotal (95% CI)			**31**			**27**	**9.5%**	**-0.06 [-0.58, 0.45]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 0.24 (P = 0.81)								
Total (95% CI)			**333**			**472**	**100.0%**	**0.39 [0.06, 0.73]**
Heterogeneity: Tau² = 0.24; Chi² = 45.51, df = 10 (P < 0.00001); I² = 78%								
Test for overall effect: Z = 2.32 (P = 0.02)								
Test for subgroup differences: Chi² = 8.02, df = 2 (P = 0.02), I² = 75.0%								



(b) Aquatic exercise vs. Land-based exercise

Study or Subgroup	Aquatic exercise Mean	SD	Total	Land-based exercise Mean	SD	Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
2.3.1 Osteoarthritis								
Foley 2003	37.1	12.7	35	31.4	12.7	35	16.0%	0.44 [-0.03, 0.92]
Lim 2010	38.8	7.7	24	40.4	7.9	22	10.7%	-0.20 [-0.78, 0.38]
Lund 2008	43	2.4	26	43.8	2.5	20	10.4%	-0.32 [-0.91, 0.27]
Wang 2011	73	12	26	74	11	26	12.2%	-0.09 [-0.63, 0.46]
Subtotal (95% CI)			**111**			**103**	**49.3%**	**0.01 [-0.26, 0.28]**
Heterogeneity: Chi² = 5.07, df = 3 (P = 0.17); I² = 41%								
Test for overall effect: Z = 0.08 (P = 0.94)								
2.3.2 Rheumatoid Arthritis								
Eversden 2007	73	22.22	43	77	22.22	42	19.8%	-0.18 [-0.60, 0.25]
Hall 1996	-33	16	35	-28	13	34	15.9%	-0.34 [-0.81, 0.14]
Subtotal (95% CI)			**78**			**76**	**35.7%**	**-0.25 [-0.57, 0.07]**
Heterogeneity: Chi² = 0.24, df = 1 (P = 0.62); I² = 0%								
Test for overall effect: Z = 1.54 (P = 0.12)								
2.3.3 Osteoporosis								
Arnold 2008	89.29	11.71	31	90.29	8.57	33	15.0%	-0.10 [-0.59, 0.39]
Subtotal (95% CI)			**31**			**33**	**15.0%**	**-0.10 [-0.59, 0.39]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 0.39 (P = 0.70)								
Total (95% CI)			**220**			**212**	**100.0%**	**-0.10 [-0.29, 0.09]**
Heterogeneity: Chi² = 6.81, df = 6 (P = 0.34); I² = 12%								
Test for overall effect: Z = 1.02 (P = 0.31)								
Test for subgroup differences: Chi² = 1.50, df = 2 (P = 0.47), I² = 0%								



Total=number of particpants in the study group