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SYSTEMATIC REVIEW

The effect of aquatic exercise on physical functioning in the older adult: a systematic review with meta-analysis

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Abstract

Background: ageing and sedentary behaviour cause negative changes in the neuromuscular systems of healthy older adults resulting in a decrease in physical functioning. Exercising in water (aquatic exercise, AE) has been shown to be effective at improving physical functioning in this population; however, no systematic review with meta-analysis has been published.
Purpose: to investigate the effect of AE on physical functioning in healthy older adults compared to control or land-based exercise (LE) through a systematic review with meta-analysis of randomised controlled trials.
Data sources: Medline, Embase, Cinahl, PEDro, SPORTDiscus, Web of Science, Cochrane Library, published before 31st December 2015.
Study selection: in total, 28 studies met the inclusion criteria and were included in the systematic review; 24 studies with 1,456 subjects (89% female) and with mean age 66.4 years were included in the meta-analysis.
Data extraction: data were extracted and checked for accuracy by three independent reviewers.
Data synthesis: size of treatment effect was measured using the standardised mean difference with 95% confidence intervals (CIs).
Results: compared to control interventions, AE had a moderate positive effect on physical functioning 0.70 [95% CI 0.48 to 0.92]. Compared to LE, AE had a small positive effect on physical functioning 0.39 [0.12 to 0.66].
Limitations: there is a high risk of bias and low methodological quality in the studies particularly when comparing AE to LE with possible over estimation of the benefit of AE.
Conclusions: AE may improve physical functioning in healthy older people and is at least as effective as LE.

Keywords: *aquatic exercise, older adults, systematic review, physical functioning, activity limitations*

Introduction

The improvements in healthcare and life style have enhanced life expectancy and thus active life years are increasing. After early adulthood, there is an association between increased age and decreased physical functioning which has led to increased financial demands on healthcare services [1]. Finding methods to slow or reverse the decrease in physical functioning has therefore become a major focus for research.

Physical activity through the life course has long been recommended to limit the decline in physical functioning. An increase in daily physical activity can slow or partially reverse the negative effect of ageing on function and prevent the progression of chronic and disabling conditions [2]. Many different modes of physical activity have been recommended to maintain or improve physical functioning including strength training, aerobics, walking and aquatic exercise (AE). AE is a popular exercising method for a wide range of populations including healthy older adults.

To our knowledge, only one systematic review has been published investigating the effect of AE on physical fitness in healthy older adults. This review [3] indicated that AE three times per week significantly improves physical function. However, this study included both randomised and non-randomised clinical trials and lacked a meta-analysis. Therefore, the purpose of this study was to investigate the effect of AE on physical functioning in healthy older adults compared to no intervention (control) and land-based exercise (LE) through a systematic review with meta-analysis of randomised controlled trials (RCTs).

Methods

Eligibility criteria

Studies included into our review fulfilled the following criteria according to the PICOS system (Population, Intervention, Comparison, Outcome and Study design) [4]. Population included participants with a mean age ≥ 55 year old with a lower age limit of 50 years, male or female and no diagnosis of disease. Frail older adults were included but only if there was a medical screening excluding the presence of another diagnosis, e.g. osteoarthritis, cardiac disease, osteoporosis/osteopenia or neurological insult. We included all interventions that could be classified as exercise in an aquatic environment (AE) with no limitation on the type of exercise. Studies were included if they had either a control group (C) and/or LE comparison group. Outcomes used in the study had to measure physical functioning and the study had to be of RCT design.

Search strategy and study selection

For this systematic review and meta-analysis, we performed a broad search of seven databases (Medline, EMbase (excluding Medline), Cinahl, Pedro, SPORTDiscus, Web of Science, Cochrane library (clinical trials)) using a comprehensive combination of keywords. The keywords used were elderly OR older people OR older population OR older adults OR ageing OR senior AND aquatic therapy OR aquatic exercise OR water therapy OR hydrotherapy OR aquatic physiotherapy OR water exercise OR aquatic rehabilitation OR pool exercise OR water rehabilitation OR aquatic physical therapy OR aquatics OR swimming intervention. The search was performed by two persons independently and included publications appearing before 31st December 2015 with no language limitations. An example of the search parameters, for Medline, can be found in Appendix 1 (see the supplementary data on the journal website http://www.ageing.oxfordjournals.org). Additionally, all assessed full texts, systematic reviews and guidelines found were searched by hand for possible additional studies. Thesis titles were searched through Proquest. A search of registered and published protocols (ISRCTN registry, ClinicalTrials.gov, Australian New Zealand Clinical trials registry (ANZCTR) and Brazilian registration of clinical trials) was also performed.

Duplicates were removed using Endnote© (Endnote X7, Thomson Reuters, USA). Based on title, animal studies and non-relevant studies were excluded. Following this, abstracts were read and non-clinical trials or intervention studies were excluded. At each stage, agreement on inclusion/exclusion between two reviewers (BW and DD was required before next stage was initiated. Full text articles for the remaining studies were retrieved and read by three independent reviewers (BW, OA and KR) and a fourth reviewer (DD) was consulted as necessary.

Data extraction

Intervention description, inclusion/exclusion criteria, baseline data and post intervention values for all outcomes were extracted by two reviewers (OA and VM) and checked for accuracy by a third reviewer (BW). Where possible, intention-to-treat data were extracted for follow-up measurements otherwise per protocol data were extracted.

Outcome measure selection

The data for all outcomes measuring different constructs of physical function, in line with Rikli and Jones [5], were extracted and included in the qualitative and quantitative synthesis. The various functional traits of muscle were described using four distinct sub-groups; maximum strength, muscle power, muscle endurance and respiratory muscle function. The remaining outcomes were divided into distinct sub-groups; agility, postural stability, walking ability, flexibility, aerobic power and self-reported functioning. In cases where multiple muscle groups were tested, the results for only one muscle group or one or more suitable outcome measure was used in the same study we followed *a priori* ranking list with highest ranked outcome measure taken in preference [6] (Ranking lists can be found from Appendix 4 in the supplementary data on the journal website http://www.ageing.oxfordjournals.org).

Statistical synthesis

The meta-analysis was performed using Review Manager (RevMan, Version 5.3. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014). The size of effect was calculated as the standardised mean difference (SMD) and 95% confidence intervals (CIs). In this study, a SMD of 0.2–0.5 was considered as small, 0.5–0.8 medium and ≥0.8 a large effect. For all analyses, we used an inverse-variance weighted random-effects model that incorporates heterogeneity into the model. High heterogeneity, as measured with I^2, was expected due to the combination of different outcome measures [7]. Two meta-analyses were performed one comparing AE to C and the second comparing AE to LE. Standard deviation was calculated from standard error. When two different aquatic interventions had been investigated and included in the meta-analysis, the size of the control group was divided by two [8]. Where necessary, data were multiplied by −1, therefore a positive effect indicates a result in favour of AE [9].

Additional analysis

Post hoc sensitivity tests were performed investigating the effects of dropout rate (<15% and ≥15%), methodological quality (Delphi ≥4), age (<68 and ≥68 years old), training frequency (<3 or ≥3 times a week) and effects of AE at different International classification of function, health and disability (ICF) levels (body structure and function or activities and participation). Percentage (%) of dropouts was calculated using baseline sample size and number of participants who did not attend post intervention measurement.

Methodological quality, risk of bias and publication bias assessments

Methodological quality was assessed using the 9-point Delphi scale [10]. The maximum an exercise intervention study can generally score is 7 because of the difficulties in blinding the participants and therapist from the intervention. Scores of <4 and ≥6 are considered to have low and high methodological quality, respectively. Risk of bias was assessed using the Cochrane Risk of Bias assessment [11]. Additionally, trial size, power analysis and centre status were extracted to give additional information on possible risk of bias [12]. Assessment of methodological quality and risk of bias were performed independently by at least two of three reviewers (BW, OA and JL) and compared. In case of disagreement, consensus was found by consulting a fourth reviewer (DD). Small study effect was assessed through interpretation of funnel plot asymmetry [13].

Results

In total, 2,244 relevant titles were found, 67 articles were accessed for eligibility and 28 studies [14–26, 28-36, 41–46] were retained in the qualitative and 24 [14–19, 21–26, 28–35, 42, 44–46] in the quantitative synthesis of this review (Figure 1). In total 16 studies compared AE to a control intervention (three compared two different aquatic interventions), 6 compared aquatic to LE and 6 compared aquatic with a land-based and a control intervention.

Participants

In total, data were extracted for 1,456 (AE *n* = 724, LE *n* = 309 and C *n* = 423) participants of which 89% were female with a mean age range of 55.4–82.0 years and mean age of 66.4 years (Appendix Table 1). Self-reported pre-study physical activity was mostly described as sedentary or not participating in regular intensive exercise. Nevertheless,

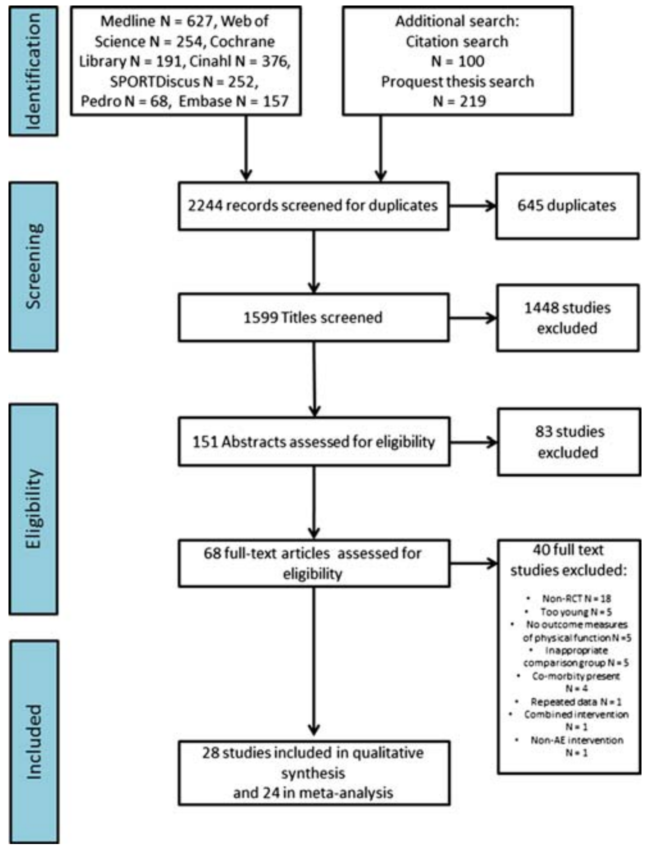

Figure 1. Flow diagram showing the study screening process and search results.

Bento *et al.* [14] stated that 77% reported themselves as either very active or active and Graef *et al.* [15] reported that exercise participants had been exercising in water for several months prior to recruitment. Additional leisure time physical activity during the intervention period was not measured in any of the included studies.

Methodological quality risk of bias and small study bias of included studies

Methodological quality is shown in Appendix Table 1 and eight studies could be considered as having high quality [16–20]. Risk of bias was either unclear or high for all studies. Scoring for each individual criterion of the Delphi scale and risk of bias as well as funnel plots for each meta-analysis are shown in Appendices 3, 5 and 6, respectively (see the supplementary data on the journal website http://www.ageing.oxfordjournals.org). Power analysis was conducted in six studies [15–18, 20, 21], *a priori* sample size was calculated in three [16, 18, 20] with sufficient recruitment met in one [18]. All studies were conducted as single centre interventions. Two studies had accessible protocols [19, 20]. Only five studies directly reported performing the outcome measures before randomisation [16, 22–25]. While 17 studies reported performing the outcome measures after the training period, only three [15, 22, 23] reported their exact timing (less than 1 week).

Aquatic exercise interventions

A summary description of the interventions, intensity and dose for each study can be found in Appendix Table 1. Types of AE utilised in the studies were mainly a mixture of strength, endurance and flexibility exercises for the upper and lower limbs. One study utilised deep water running [26] and one swimming [16]. Planned exercise dose varied from 80 to 250 min/week for 5–32 weeks, frequency of treatment was either once (n = 1), twice (n = 12), three (n = 14) or five (n = 1) times a week. Intensity of aerobic training ranged between 40–70% of heart rate reserve, 60–80% of heart rate maximum or 11–16 of perceived rate of exertion (Borg 6–20 scale) and 4–9 (Borg 10 scale), i.e. moderate to high intensity [27]. Actual training intensity achieved during the intervention was reported in only one study [26]. Harms were reported in five studies [16, 20, 26, 28–30] with a total of n = 8 and n = 6 participants reporting a harm as a direct result of the AE and LE, respectively.

Comparison interventions

Intensity of land-based training was reportedly always set at the same level as the aquatic training; however, they were not always comparable. In two studies, land-based training consisted of walking alone [16, 31], one study had a poorly described LE programme [18], one study utilised similar exercises to the AE but performed on the floor [19], one used the same exercises as in AE but performed standing while holding on to the back of a chair [32], one performed the same AE exercises but without resistance [22] and one used Pilates [33].

Effect of aquatic exercise physical functioning

Data from four studies could not be synthesised into the meta-analysis due to insufficient reporting and no data were provided from authors. Incomplete data reporting for relevant outcomes have been denoted with italics within Appendix Table 1. Further, the control group from Bocalini *et al.* (2008) [11] was not involved in the randomisation process and therefore excluded. For Elbar *et al.* [17] which was of a randomised crossover design, only data from the first phase were included.

Aquatic exercise compared to control

AE compared to C had a moderate effect on physical functioning 0.70 [95% CI 0.48 to 0.92] in favour of AE (Figure 2). Impact of the results from Bocalini *et al.* (2010) [28] (publication bias), Kim *et al.* [34] (significant baseline differences) and Ruoti *et al.* [35] (baseline difference and unexplained loss from baseline to post intervention in control group) on the overall effect sizes appears disproportionate. Removal of these study results only slightly decreases the effect on physical functioning 0.61 [0.46 to 0.75] in favour of AE. Heterogeneity (I^2) was 32%.

Aquatic exercise compared to land-based exercise

AE appears to have a small and significant advantage over LE in improving physical functioning 0.39 [0.39 to 0.66] (Figure 3). However, the comparison group (walking) in Bocalini *et al.* [31] was a non-comparable intervention. Removal of this study resulted in no significant benefit (0.17 [−0.03 to 0.36]) of aquatic over LE. Heterogeneity (I^2) for this analysis was 75%.

Sensitivity analyses

Results for all sensitivity tests can be found from Appendix 7 (see the supplementary data on the journal website http://www.ageing.oxfordjournals.org).

Dropout rates

Study dropouts ranged from 0% to 45%, 0% to 36% and 0% to 41% for the AE, LE and control groups, respectively (Appendix Table 1). Several studies [22, 31, 33, 36] excluded subjects from the final analysis for low adherence to exercise and in all cases counted them as dropouts and therefore did not report their data (incomplete data bias) with true intention-to-treat analysis used in only two studies [16, 19]. When including only studies with a low dropout rate (<15%), the effect of AE compared to C was similar to the main analysis. The comparison of AE to LE was smaller, although still significant, compared to the main analysis (Appendix 7). However, the heterogeneity (I^2) for both analyses showed much smaller and non-significant values, 19% and 6%, respectively, indicating smaller variance between the studies with low dropout rates.

Age

Younger participants <68 years may benefit more from AE. In the comparison of AE to C, the effect of AE was larger in the group aged <68 years compared to ≥68 years. A similar trend was seen in the comparison of AE to LE (Appendix 7).

Training frequency

Training frequency did not seem to have an effect. When comparing AE to C and AE to LE, AE had a similar sized effect on those who trained <3 times a week compared to ≥3 times a week (Appendix 7).

Methodological quality

Excluding studies with low methodological quality <4 Delphi did not affect the overall result for either comparison of AE to C or AE to LE (Appendix 7).

ICF classification of outcomes

AE appeared to have a similar sized effect on outcomes measuring constructs of body structure and function and

Study or Subgroup	Aquatic Exercise Mean	Aquatic Exercise SD	Aquatic Exercise Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
2.1.1 Maximum strength								
Bento 2012	84.4	40.6	24	76.5	32.2	14	2.1%	0.20 [-0.46, 0.87]
Bergamin 2013	120.4	39.36	17	84.6	40.23	19	2.1%	0.88 [0.19, 1.57]
Carrasco 2012	68.28	11.2	29	60.82	19.7	15	2.2%	0.50 [-0.13, 1.13]
Carrasco 2012	82.19	21.5	29	60.82	19.7	15	2.1%	1.00 [0.34, 1.66]
Graef 2010	18.45	2.19	10	15.6	4.41	4	1.5%	0.92 [-0.31, 2.14]
Graef 2010	18.32	3.15	10	15.6	4.41	4	1.5%	0.73 [-0.48, 1.93]
Kim 2013	118.29	35.74	8	130.43	18.53	7	1.7%	-0.39 [-1.42, 0.63]
Rhodes 1995	24.9	3.8	23	24.9	5.7	14	2.1%	0.00 [-0.66, 0.66]
Takeshima 2002	37.3	7.4	15	33.7	5.3	15	2.0%	0.54 [-0.19, 1.27]
Tsourlou 2006	89.3	27.4	12	83.6	38.6	10	1.9%	0.17 [-0.67, 1.01]
Subtotal (95% CI)			**177**			**117**	**19.2%**	**0.46 [0.20, 0.72]**
Heterogeneity: Tau² = 0.02; Chi² = 10.34, df = 9 (P = 0.32); I² = 13%								
Test for overall effect: Z = 3.43 (P = 0.0006)								
2.1.2 Muscular power								
Carrasco 2012	100.81	24.8	29	87.29	20.9	15	2.2%	0.56 [-0.07, 1.20]
Carrasco 2012	91.76	24.8	29	87.29	20.9	15	2.2%	0.19 [-0.44, 0.81]
Kim 2013	76.29	23.16	8	91.86	11.67	7	1.6%	-0.78 [-1.85, 0.28]
Takeshima 2002	25.2	4.4	15	22.3	4.5	15	2.0%	0.63 [-0.10, 1.37]
Tsourlou 2006	11.54	3.811	12	8.72	2.846	10	1.9%	0.80 [-0.08, 1.67]
Subtotal (95% CI)			**93**			**62**	**9.9%**	**0.35 [-0.08, 0.79]**
Heterogeneity: Tau² = 0.10; Chi² = 6.57, df = 4 (P = 0.16); I² = 39%								
Test for overall effect: Z = 1.58 (P = 0.11)								
2.1.3 Muscular endurance								
Bento 2012	14.58	2.1	24	12.23	1.36	14	2.1%	1.23 [0.51, 1.95]
Bocalini 2010	33.6	2.6	27	23.7	2.12	15	1.6%	3.98 [2.88, 5.07]
Kovách 2013	21.6	3	17	22.3	5.9	15	2.1%	-0.15 [-0.84, 0.55]
Ruoti 1994	8.48	0.3	12	5.82	0.3	14	0.6%	8.59 [5.94, 11.24]
Shibata 2012	-14.9	4.3	15	-16.6	5.3	12	2.0%	0.35 [-0.42, 1.11]
Subtotal (95% CI)			**95**			**70**	**8.3%**	**2.40 [0.63, 4.18]**
Heterogeneity: Tau² = 3.66; Chi² = 73.50, df = 4 (P < 0.00001); I² = 95%								
Test for overall effect: Z = 2.66 (P = 0.008)								
2.1.4 Respiratory muscle function								
Ide 2005	100	34.88	19	89.28	26.75	21	2.2%	0.34 [-0.29, 0.97]
Takeshima 2002	1.78	0.37	15	1.58	0.35	15	2.0%	0.54 [-0.19, 1.27]
Subtotal (95% CI)			**34**			**36**	**4.2%**	**0.42 [-0.05, 0.90]**
Heterogeneity: Tau² = 0.00; Chi² = 0.17, df = 1 (P = 0.68); I² = 0%								
Test for overall effect: Z = 1.75 (P = 0.08)								
2.1.5 Agility								
Bento 2012	-5.12	0.46	24	-5.28	0.5	14	2.1%	0.33 [-0.33, 0.99]
Bergamin 2013	-4.49	0.76	17	-5.28	1.02	19	2.1%	0.85 [0.16, 1.54]
Bocalini 2010	-9.8	3.12	27	-14.4	2.97	18	2.1%	1.48 [0.80, 2.15]
Elbar 2013	-149.3	25	17	-167	33	18	2.1%	0.59 [-0.09, 1.27]
Kim 2013	-6.98	1.88	8	-4.99	0.7	7	1.5%	-1.28 [-2.43, -0.14]
Kovách 2013	-5.45	0.9	17	-5.6	0.8	15	2.1%	0.17 [-0.52, 0.87]
Martínez 2015	-31.84	8.4	16	-35.83	8.9	10	2.0%	0.45 [-0.35, 1.25]
Simmons 1996	34	4.1	10	23.6	1.8	10	1.3%	3.15 [1.75, 4.54]
Takeshima 2002	28.4	4.4	15	23.9	5.7	15	2.0%	0.86 [0.11, 1.61]
Tsourlou 2006	-5.09	0.69	12	-6.23	0.95	10	1.8%	1.34 [0.40, 2.29]
Subtotal (95% CI)			**163**			**136**	**19.1%**	**0.74 [0.25, 1.24]**
Heterogeneity: Tau² = 0.45; Chi² = 34.33, df = 9 (P < 0.0001); I² = 74%								
Test for overall effect: Z = 2.96 (P = 0.003)								
2.1.6 Postural stability								
Elbar 2013	-86.9	62	17	-73.9	31	18	2.1%	-0.26 [-0.93, 0.40]
Kim 2013	3.14	1.5	8	4.77	3.85	7	1.7%	-0.54 [-1.58, 0.50]
Subtotal (95% CI)			**25**			**25**	**3.8%**	**-0.34 [-0.90, 0.22]**
Heterogeneity: Tau² = 0.00; Chi² = 0.20, df = 1 (P = 0.66); I² = 0%								
Test for overall effect: Z = 1.20 (P = 0.23)								
2.1.7 Flexibility								
Bento 2012	5.29	11.94	24	-1.7	15.68	14	2.1%	0.51 [-0.16, 1.18]
Bergamin 2013	13.08	6.77	17	10.37	7.62	19	2.1%	0.37 [-0.29, 1.03]
Bocalini 2010	18.9	4.68	27	13.1	4.24	18	2.1%	1.26 [0.61, 1.92]
Kim 2013	10.13	6.56	8	10.27	5.48	7	1.7%	-0.02 [-1.04, 0.99]
Kovách 2013	8.3	6.8	17	-4.9	8.1	15	1.9%	1.73 [0.90, 2.56]
Martínez 2015	-11.2	3.52	16	-13.73	4.19	10	1.9%	0.65 [-0.17, 1.46]
Rhodes 1995	31.4	11.1	23	30.3	8.7	14	2.1%	0.10 [-0.56, 0.77]
Takeshima 2002	16.6	4.7	15	8.5	8.3	15	2.0%	1.17 [0.39, 1.95]
Tsourlou 2006	23.6	6.235	12	22.87	7.89	10	1.9%	0.10 [-0.74, 0.94]
Subtotal (95% CI)			**159**			**122**	**18.0%**	**0.66 [0.28, 1.04]**
Heterogeneity: Tau² = 0.19; Chi² = 18.35, df = 8 (P = 0.02); I² = 56%								
Test for overall effect: Z = 3.40 (P = 0.0007)								
2.1.8 Walking ability								
Bento 2012	596.8	77.1	24	558.3	79.4	14	2.1%	0.48 [-0.19, 1.15]
Kovách 2013	525.3	84.4	17	416	63.2	15	2.0%	1.42 [0.63, 2.20]
Martínez 2015	-6.7	1.23	16	-7.92	2.36	10	1.9%	0.68 [-0.14, 1.49]
Subtotal (95% CI)			**57**			**39**	**6.0%**	**0.84 [0.28, 1.39]**
Heterogeneity: Tau² = 0.10; Chi² = 3.29, df = 2 (P = 0.19); I² = 39%								
Test for overall effect: Z = 2.94 (P = 0.003)								
2.1.9 Aerobic power								
Broman 2006	27.2	2.1	15	23.3	4	9	1.8%	1.28 [0.37, 2.20]
Rhodes 1995	21.2	3.8	23	18.9	4.3	14	2.1%	0.56 [-0.11, 1.24]
Ruoti 1994	26.95	0.5	12	21.84	0.6	14	0.5%	8.89 [6.16, 11.63]
Taunton 1996	21.1	3.3	23	20.9	3.6	18	2.2%	0.06 [-0.56, 0.67]
Subtotal (95% CI)			**73**			**55**	**6.6%**	**1.98 [0.32, 3.64]**
Heterogeneity: Tau² = 2.43; Chi² = 40.32, df = 3 (P < 0.00001); I² = 93%								
Test for overall effect: Z = 2.34 (P = 0.02)								
2.1.10 Self-reported physical functioning								
Sato 2007	44.2	7.6	10	34.7	11.6	4	1.4%	1.01 [-0.23, 2.26]
Sato 2007	45.4	6	12	34.7	11.6	4	1.4%	1.34 [0.09, 2.59]
Shibata 2012	49.6	5.8	15	45.1	7.7	12	2.0%	0.65 [-0.13, 1.43]
Subtotal (95% CI)			**37**			**20**	**4.9%**	**0.88 [0.30, 1.47]**
Heterogeneity: Tau² = 0.00; Chi² = 0.89, df = 2 (P = 0.64); I² = 0%								
Test for overall effect: Z = 2.95 (P = 0.003)								
Total (95% CI)			**913**			**682**	**100.0%**	**0.70 [0.48, 0.93]**
Heterogeneity: Tau² = 0.49; Chi² = 211.27, df = 52 (P < 0.00001); I² = 75%								
Test for overall effect: Z = 6.23 (P < 0.00001)								
Test for subgroup differences: Chi² = 21.37, df = 9 (P = 0.01), I² = 57.9%								

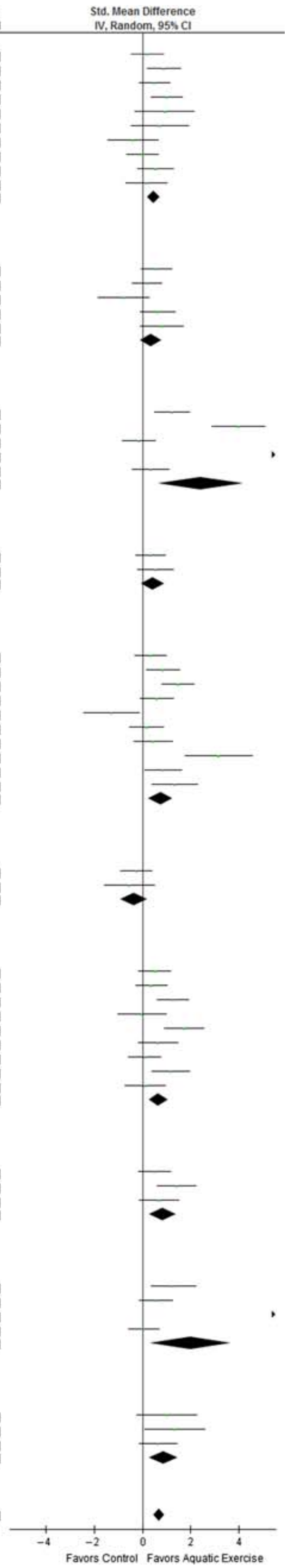

Figure 2. Forest plots showing the effect of AE on physical functioning when compared to control interventions.

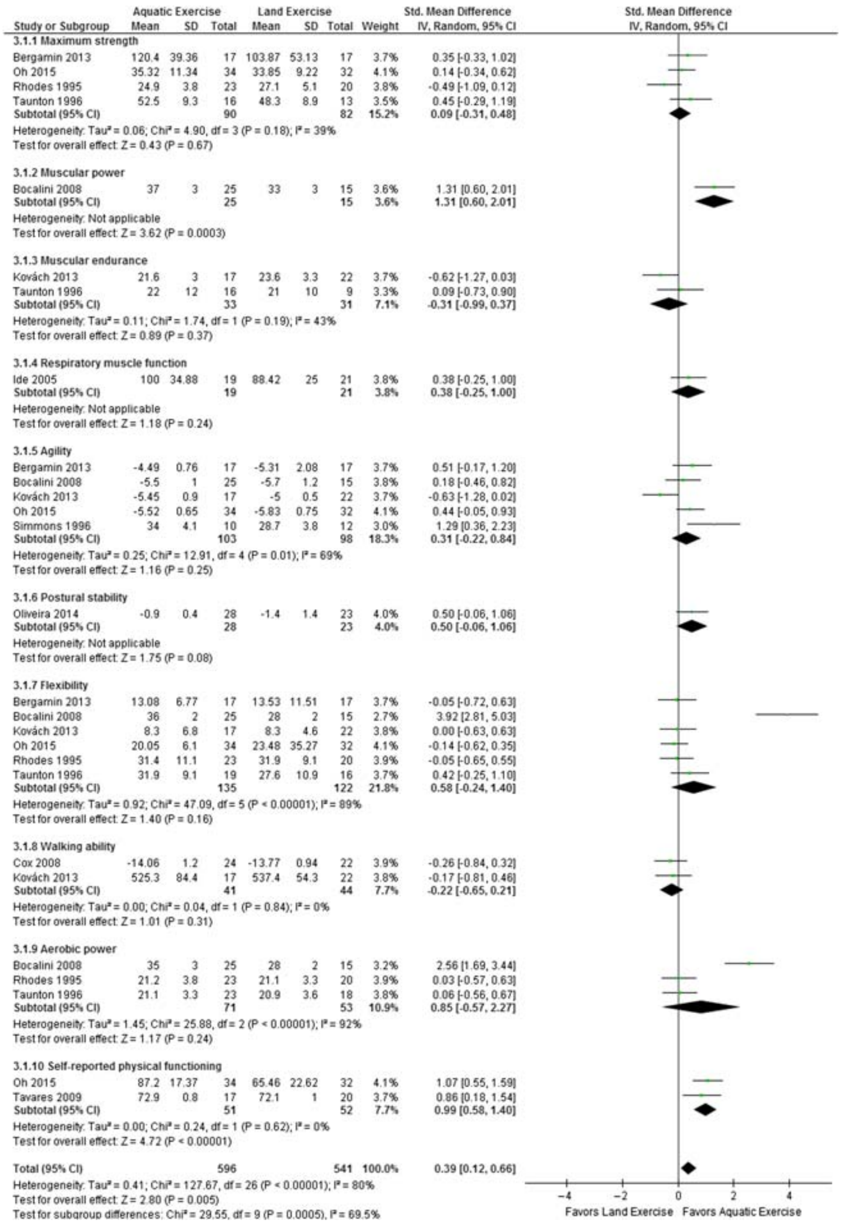

Figure 3. Forest plots showing the effect of AE on physical functioning when compared to LE.

activity and participation. This was seen equally in both AE compared to C and AE compared to LE (Appendix 7).

Discussion

This study is the first systematic review, investigating the effects of AE for healthy older adults, to include a meta-analysis. Our results indicate that exercise in water at moderate to high intensities irrespective of modality may have moderate sized positive effects on physical functioning in healthy older adults when compared to a no training, i.e. a control group. Further, when the comparison group participated in LE, our results suggest that AE may be slightly more effective at improving physical function. However, due to high risk of bias, high heterogeneity and low methodological quality, these results have to be interpreted with care. Nevertheless, AE appears to be at least as effective at improving function as LE. We are unable to show longer term effects of AE due to lack of data.

Optimal physical functioning in older adults can be measured using different constructs [37]. Our results show that AE may have a moderate overall positive effect on constructs at different levels of the ICF, i.e. muscle power and flexibility (body function) and agility and walking ability (activities). Further, when compared to LE, AE had a similar effect on both body function and structures and activities (Figures 2 and 3, Appendix 7). In contrast to the systematic review of Bergamin *et al.* [3] who stated that AE three times a week was an optimal frequency, we found no difference between training twice and three times a week. The difference between conclusions may result from our more comprehensive search and inclusion criteria which identified 28 studies for inclusion compared to 9 in the Bergamin *et al.* study [3]. Further, our study used a meta-analysis on which the conclusion is based. While adults under the age of 68 years old appeared to benefit more from AE, these results should be considered in light of the slightly higher intensity training utilised in these studies and the high heterogeneity in the meta-analysis (82–91%).

Muscle strength, power and mass are all associated with functional capacity [2] and although resistance training on land has been shown to improve maximal muscle force in older adults, this improvement does not always result in improvements in function [38]. In contrast, the findings of this review show similar effect sizes in both muscle capacity and physical functioning suggesting a carryover effect from AE (Figures 2 and 3) [2]. The aquatic environment provides situations of instability by using the effects of turbulence which could promote greater improvements in body balance reactions [39]. The LE interventions were in general more static in nature and would not have challenged the neuromuscular systems as much as the AE interventions. Further, it is worth noting that only Bocalini *et al.* (2010) [28] reported baseline times of ≥13.5 s for the timed- or 8 ft up-and-go test (utilised in 9 out of the 13 studies measuring agility). While this study also reported the largest ES for the effect of AE on agility, the study of Bento *et al.* [14] reported no effect of AE however the participants in this study were already active or very active. Therefore, AE could be more beneficial for those older adults with lower levels of physical functioning.

The present study has a number of strengths, including the use of *a priori* inclusion criteria for the outcome measures based on previous work [5, 6] and using SMD to express the overall size of effect of AE on physical functioning allowing combination of results measured with other outcomes. However, this method does hinder the direct interpretation of the results for clinical application. The comprehensive search with no language or quality limitations reduced the possibility of omitting appropriate studies. The sensitivity analysis assessed the impact of different methodological and reporting biases, however, no change in conclusions resulted from these analyses. Few studies reported harm resulting from the interventions indicating AE is safe for this population. However, the results of this study are still open to significant bias due to limitations in the methodology, small study bias and high or unclear risk of bias in the included studies. In particular, the choice of type of LE overestimated the effectiveness of AE over LE. While the combining of different outcome measurements (as SMDs) into the same meta-analysis presents the effect of AE on physical functioning as a whole, there is a risk of studies with higher numbers of outcomes to bias the results. Interpretation of the meta-analyses should also include an interpretation of the results from each individual construct (sub-group) analyses. The percentage of women in analysed studies was 89% and was an inclusion criterion for 16 of these, limiting the applicability of the results to male populations. Further, even though 24 of the studies were published after the first CONSORT statement in 2001 [40], reporting of methods, dropouts and results were often incomplete. In particular, the randomisation process was not completely reported. Only 9 of these 28 studies had a flow chart showing participant recruitment and effect of high attrition rate was often ignored in the statistical analyses. Additionally, the sample size of the included studies was often small and even though a random-effects model was utilised, the impact of this bias was not always controlled for. Moreover, only six studies performed a power analysis and three performed a sample size calculation *a priori*. There was insufficient data to perform a meta-analysis investigating the long-term effects of AE on older adults due to lack of follow-up measurements. No studies measured the leisure time physical activity of the participants during the intervention period thus making it difficult to attribute all the effects directly to the exercise interventions alone. While the protocol for the systematic review was not registered, creating a potential source of bias, a full protocol is available from the first author. This openly documents the original protocol and changes made during the revision process. Future studies should address the methodological weaknesses described in this review to ensure that AE is appropriately utilised in the community. Additionally they should focus on the long-term adherence to different exercise modalities.

Conclusion

Based on the results from our systematic review with meta-analysis, we can conclude that AE appears to be effective at maintaining and improving physical function in healthy older adults. When compared to LE, AE appears to be at least as effective and could be used as an alternative training modality when LE is not feasible or desired.

Key points

- AE may have a moderate effect on physical functioning in older healthy adults.
- AE is at least as effective at improving function as LE.
- Further high quality research is required to investigate the optimal type of AE for this population.

Supplementary data

Supplementary data mentioned in the text are available to subscribers in *Age and Ageing* online.

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Conflicts of interest

None declared.

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