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Systematic Review

Systematic Review of Published Research on Aquatic Exercise for Balance in the Elderly

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Abstract

Background and purpose. Exercise in water is a therapeutic intervention that can improve balance and prevent falls in elderly. This review examines published research that tests the effectiveness of aquatic exercise in healthy elderly for its effects on measures of functional balance.

Methods. A systematic search was made of 5 electronic databases for trials of aquatic exercise in populations of over 60 years with pre- and postintervention measurement of functional balance. Reference lists of articles meeting all criteria were hand-searched. Quality of studies was assessed using the Downs and Black assessment tool.

Results. Thirteen studies were identified for the review. There are methodological weaknesses in most studies, e.g., failure to provide blinded assessors or show power calculations. Overall, the research found that aquatic exercise groups improved on balance measures significantly more than control groups, but in the few high-quality studies which compared aquatic- and land-exercise there was no significant difference between groups.

Discussion and conclusions. Aquatic exercise is an option for therapists in efforts to promote balance in the elderly. However, there is limited evidence comparing aquatic with land-based programs. Recommendations are made regarding further research.

Key words: Aquatic exercise, Balance training, Elderly, Systematic review.

Background and Purpose

There are today increasing numbers of older people who have functional problems due to poor balance, and a growing population of fallers.[1] It is unclear whether this is a function of increased numbers of elderly people, combined with increasingly sedentary habits, or a function of other causes.[2] Reviews of the effects of exercise in older adults have found that exercise can mitigate or reduce the risks of several age-related health problems, including cardiovascular disease, diabetes, respiratory disease, arthritis, dementia and cancer.[3,4] Some authorities have therefore argued for training programs to enable the healthy elderly to improve balance function and strength, and thereby to prevent, or at least minimize, the risk of falls with their debilitating orthopedic and other consequences. This might also reduce the tendency of some older people to restrict their function unnecessarily due to fear of falling. In this context a variety of treatment approaches have been used, including Tai Chi, yoga and exercise programs, as well as education and environmental modifications.

Several studies have appeared recently[5,6,7] that found that exercises in water were effective as a therapeutic intervention to improve functional balance in the elderly. There is a need to synthesize and assess the quality of this research before important decisions are taken with regard to resources and treatment approaches.

Proponents of aquatic exercise for improving balance in the elderly suggest a number of reasons why it might be effective. Firstly, the reduction in ground reaction forces due to buoyancy means that the water environment would be an appropriate low impact medium for elderly people with joint arthropathies, osteopathies, and obesity who might be otherwise unwilling to exercise.[5] Buoyancy can give the same effect as the weight-relieving harness used in some treadmill training programmes[8] while still leaving the user free to move. Secondly, the relative viscosity of water compared to air means that movements are slower. One effect of this is that exercisers in water have more time for neurological processing necessary to detect movement errors and generate balance reactions compared to what is available in the normal land context. Thirdly, the supportive nature of the relatively viscous medium can give the exerciser in water increased confidence for movement.[9] This is particularly important in individuals with a fear of falling. The greater time for processing and the removal of injury fears can, it is argued, give exercisers in water an increased willingness to make experiments and risk errors, knowing that they are not likely to undergo bone injury if they make mistakes.[10] This phenomenon is particularly important in treatment approaches that emphasize learning how to respond to perturbations.[6,11] Finally, other simultaneous effects of immersion, such as water pressure, warmth around joints, flotation of limbs, etc may enable participants to achieve increased ranges of movement. These features are also argued by some[12] to increase both skin sensation and proprioception, with consequent benefits for balance.

On the other hand aquatic exercise is expensive relative to other interventions such as walking therapies or Tai Chi. It would fail a test of ecological validity, since the exercises being performed are not in the context in which the exerciser normally functions. (Most research supports the idea that rehabilitation and training should be task and context specific.[13]) Reduced fear in the water may not translate to reduced fear back on land. The claims for increased skin sensation and proprioception in the water may not be relevant if participants cannot retain this increased awareness after leaving the water.

One of the factors that may cause increased risk of falls in the elderly is their inability to recruit muscle force quickly enough to make postural adjustments in the short time frames available in functional challenges.[14] Training for improved power has been advocated as a way of countering this problem, and there is some evidence supporting this view.[15] But is not clear where aquatic exercise fits here: on the one hand the viscosity of the medium could demand greater forces during exercises, and the relative security could give participants confidence to try jumps and fast movements that are normally beyond them on land. On the other hand the greater time available and the reduced fear of impacts during falls might allow exercisers to be content with normal speeds of force generation and therefore not train effectively for what is needed out of the water.

So there is a need for evidence that skills learnt in the pool can transfer to normal contexts successfully, and that those skills can be learnt more successfully in the aquatic environment than on land, before exercises in water can be recommended as more effective than land treatments. It is therefore important to review the current research on the effects of aquatic exercise on the elderly through measures of balance and balance function. The current review includes published studies which compare the effects of aquatic therapy with comparable land exercises, or with a control group.

A scoping exercise involving using the PICOSS algorithm[16] and initial searches of the literature concluded with the following focus for the review:

- Population: Healthy elderly people over 60 years, excluding those with neurological pathologies and severe medical pathologies affecting functions of balance and walking, and excluding people with contraindications to aquatic training such as cardiovascular conditions, skin conditions, and continence problems
- Intervention: Aquatic exercise programs or exercise in water
- Comparison: Land exercise group, or a control group
- Outcomes: Validated measures of 'Balance' such as the Berg Balance Scale, Tinetti, Step test, Y balance test, Functional Reach Test
- Setting: Independently living, either in the community, or in retirement communities
- Study design: RCTs or quasi-randomized trials
- It is hard to define and recruit a 'healthy' elderly population, since the probability is high that members of this group will have conditions such as arthritis or cardiovascular disease, even if such conditions are not so serious as to limit walking or everyday function to a significant degree. For example, in the groups of 'healthy' elderly recruited by Lord et al[17] for their study of water exercise 60% reported arthritis, a third reported high blood pressure and a quarter had foot problems.

Although the original intention had been to restrict this review to research conducted with healthy elderly participants, it was decided to include studies that were conducted specifically with participants with osteoarthritis and osteoporosis, since many of the participants in the studies on 'healthy' elderly would include people with these conditions.

The outcome measures included for this review were those specifically validated to assess the function of balance, such as the Berg Balance Test, the Star excursion test or the timed Up and Go test, but measures of body sway were also accepted.

The aim of this current review therefore is to review and synthesize published research that tests the effectiveness of aquatic exercise in healthy older adults for its effects on measures of functional balance.

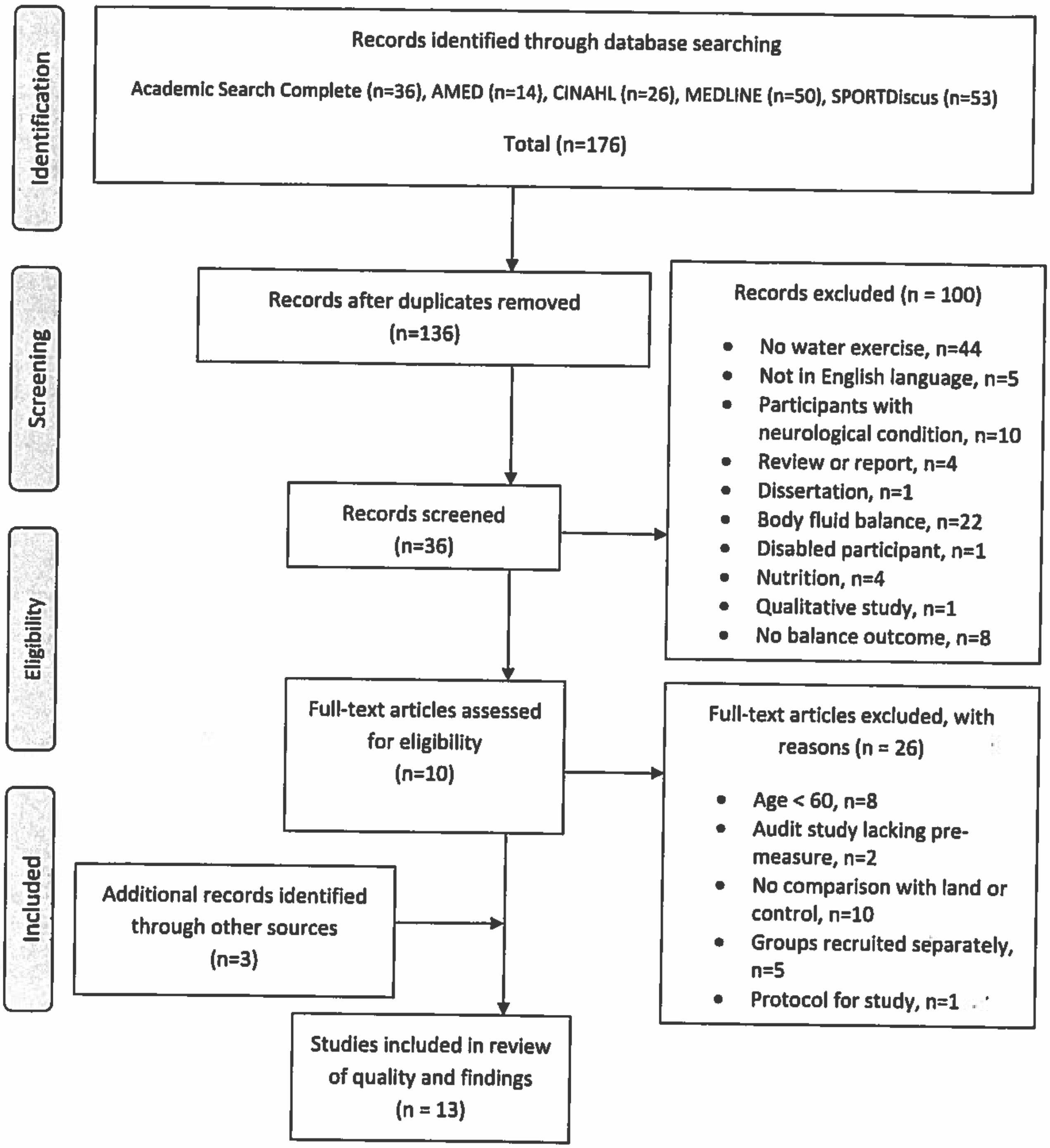
Methods

This systematic review was planned and executed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement for reporting systematic reviews.[18]

Search Strategy

A comprehensive structured search was conducted in November 2013 by 2 independent researchers of the following 5 electronic databases: Academic Search Complete, AMED, CINAHL, MEDLINE, and SPORTDiscus. A search of the Cochrane Library revealed no equivalent systematic review. There was no date restriction. A combination of searching by

Figure. PRISMA Flow Diagram



subject heading and keyword searching was employed. Subject headings varied according to the database: in CINAHL the CINAHL terms used were *Elderly, Balance training: physical, Exercise therapy: balance, Balance: postural, Hydrotherapy.* Keywords used were *elderly, elder, older, senior, aged, aging, ageing, balance, postural balance, postural control, hydrotherapy, water based exercise(s), water exercise(s), aquatic exercise(s)* and *aquatic therapy*. The Boolean operator 'OR' was used to maximize the hits for each of the target population (elderly), the intervention (water based exercises) and the outcome (balance measures). These searches were then combined using 'AND'. From the resultant search results all titles were initially screened using the inclusion and exclusion criteria before the abstracts of all relevant articles were read. Where there was any doubt the abstract and/or full text was read to determine if inclusion criteria were met. Disagreements were resolved by discussion between the 2 researchers following an independent filtering process. Hand searching of the reference lists of all relevant articles was conducted to ensure that no relevant studies were missed.

Table 1. Characteristics of Selected Studies

Authors	Year and Country	Journal	Title	Population	Exclusions (in addition to cardiac/urinary/skin conditions contra to aquatic exercise)
Arnold CM Busch AJ Schachter CL Harrison EL Olszynski WP	2008 Canada	*Physiother Can* 60(4):296-306	A Randomized Clinical Trial of Aquatic versus Land Exercise to Improve Balance, Function, and Quality of Life in Older Women with Osteoporosis	Elderly females (over 60, mean 67.7) with osteoporosis	Neuro conditions affecting ADLs; uncontrolled thyroid; recent exercise programs
Arnold CM Faulkner RA	2010 Canada	*J Aging Phys Activity* 18:245-260	The Effect of Aquatic Exercise and Education on Lowering Fall Risk in Older Adults with Hip Osteoarthritis	Elderly M & F (over 65, mean 74) with hip arthritis and minimum 1 fall risk factor	Joint surgery; participation in exercise program; neuro condition affecting mobility
Avelar NCP Bastone AC Alcantra MA Gomes WF	2010 Brazil	*Rev. Bras. Fisioter.* 14(3):229-236	Effectiveness of aquatic and non-aquatic lower limb muscles endurance training in the static and dynamic balance of elderly people	Community dwelling elderly (over 60, mean 69), many with history of falls	Undergoing other physical therapy Rs; drugs affecting balance
Bergamin M Ermolao A Tolomio S Berton L Sergi G Zaccaria M	2013 Italy	*Clin Interventions Aging* 8:1109-1117	Water-versus land-based exercise in elderly subjects: effects on physical performance and body composition	Community dwelling elderly (over 65, mean 71.2)	Arthritic movements limited by pain; Neuro conditions; Recent exercise programs
Devereux K Robertson D Briffa NK	2005 Australia	*Australian J Physiother* 51(2):102-108	Effect of a water-based program on women 65 years and over: A randomized controlled trial	Community-dwelling elderly females (over 65, mean 73.3)	Neuro or inner ear conditions;
Elbar O Tzedek I Vered E Shvarth G Friger M Melzer I	2013 Israel	*Arch Gerontology Geriatrics* 56:134-140	A water-based training program that includes perturbation exercises improves speed of voluntary stepping in older adults: A randomized controlled cross-over trial	Healthy elderly (64-88, mean 69.5)	Recent hydro, physical therapy or orthop surgery; BBS score over 45
Hale LA Waters D Herbison P	2012 New Zealand	*Arch Phys Med Rehab* 93(1):27-34	A randomized controlled trial to investigate the effects of water-based exercise to improve falls risk and physical function in older adults with lower-extremity osteoarthritis	Elderly (70-78, mean 75) with self-reported lower limb OA, & with minimum 1 falls risk factor	OA in joints other than hip or knee; recent hip/knee joint replacement; in exercise program
Hosseini SS Mirzaei B Panahi M Rostamkhany H	2011 Iran	*Middle-East J Sci Res* 9(5):661-666	Effect of aquatic balance training and detraining on neuromuscular performance, balance and walking ability in healthy older men	Healthy elderly men (minimum age not stated, mean 70)	History of falls; joint dislocations; chronic arthritis or dizziness

Table 1. Continued

Authors	Year and Country	Journal	Title	Population	Exclusions (in addition to cardiac/urinary/skin conditions contra to aquatic exercise)
Hosseini SS Rostamkhany H Panahi M	2011 Iran	*Ann Biol Res* 2(6):240-246	Comparisons of Berg Balance Scale following whole body vibration training and aquatic balance training in male elderly subjects	Healthy elderly (minimum age not stated, mean 70)	History of falls; joint dislocations; chronic arthritis or dizziness
Jalili M	2011 Iran	*Ann Biol Res* 2(6):489-495	Change in balance and neuromuscular performance following whole body vibration and aquatic balance training in elderly subject	Healthy elderly (minimum age not stated, mean 70)	History of falls; joint dislocations; chronic arthritis or dizziness
Kim SB O'Sullivan DM	2013 S.Korea	*J Phys Ther Sci* 25:923-927	Effects of Aqua Aerobic Therapy Exercise for Older Adults on Muscular Strength, Agility and Balance to Prevent Falling During Gait	Elderly females (minimum age not stated, mean 71)	DEXA bone density score below -1
Simmons V Hansen PD	1996 U.S.A.	*J GerontolA Biol Sci Med Sci* 51(5):M233-238	Effectiveness of Water Exercise on Postural Mobility in the Well Elderly: An Experimental Study on Balance Enhancement	Well retirement community-dwelling elderly (74-90, mean 80)	
Tsourlou T Benik A Dipla K Zafeiridis A Kellis S	2006 Greece	*J Strength Conditioning Res* 20(4):811-818	The effects of a twenty-four-week aquatic training program on muscular strength performance in healthy elderly women	Healthy community dwelling women (over 60 mean 69)	Diabetes mellitus; Neurological conditions; inflammatory disorders

Abbreviations: ADL Activities of Daily Living, BBS Berg Balance Scale,

Selection Criteria

The inclusion criteria used to select published studies for the full review were as follows: studies had to be randomized controlled trials or quasi-randomized, with pre- and post intervention analysis, but with no requirements with regard to long-term follow-up. The population of interest was healthy community-dwelling people aged over 60 years. The intervention studied had to include exercise programs in water, with no restriction on depth or temperature of the aquatic environment. Swimming programs were not included. The group for comparison could be either a control group or a parallel group doing similar land exercises. The outcome of interest was a validated measure of balance performance, including combined functional measures such as the Timed Up and Go test which includes turns and standing and sitting maneuvers. Exclusion criteria were participants with neurological conditions because of possible influences on balance, and cardiac, skin and continence conditions that preclude participation in aquatic exercise. The researchers did not follow up studies in languages other than English.

Evaluation of Methodological Quality

The 2 reviewers independently analyzed the methodological quality of the studies included using the checklist developed by Downs and Black.[19] It contains 27 items, of which 10 items cover report of study information, 3 items cover external validity, 7 items cover bias areas of internal validity, 6 items cover the management of internal validity, and 1 item relates to power calculation. All but 2 of the items are scored 0 or 1. The exceptions are the item on describing principal confounders (0, 1, or 2) and the item on power calculations (0 to 5). Disagreements in extracted data were resolved by discussion among the reviewers.

Table 2. Assessment of quality of included studies, using checklist of Downs and Black (1998)

		Checklist												
		Reporting										External Validity		
Study Number	First Author	1	2	3	4	5	6	7	8	9	10	11	12	13
		Study aim	Main outcome	Subject characteristics	Description of Intervention	Principal confounders	Outcome data	Range of results	Adverse events	Lost to follow up	Probability value (exact)	Source population	Represen-tative of population	Staff, place, facility
1	Arnold et al[5]	1	1	1	1	2	1	1	1	1	1	1	0	1
2	Arnold and Faulkner[30]	1	1	1	1	2	1	1	1	1	1	1	0	1
3	Avelar et al[32]	1	1	1	1	2	0	0	1	1	1	1	1	0
4	Bergamin et al[7]	1	1	1	1	1	1	1	0	1	1	1	0	0
5	Devereux et al[33]	1	1	1	1	1	1	1	1	1	1	1	1	1
6	Elbar et al[6]	1	1	1	1	2	1	1	0	1	1	1	0	0
7	Hale et al[31]	1	1	1	1	2	1	1	1	1	1	1	0	1
8	Hosseini et al[26]	1	1	0	1	1	1	1	0	0	0	1	0	0
9	Hosseini et al[28]	1	1	0	1	1	1	1	0	0	0	0	0	0
10	Jalili [29]	1	1	0	1	1	1	1	0	0	0	0	0	0
11	Kim and O'Sullivan[34]	1	1	0	1	1	1	1	0	1	0	0	0	0
12	Simmons and Hansen[10]	1	1	1	1	1	1	1	1	0	0	1	1	1
13	Tsourlou et al[27]	1	1	1	1	1	1	1	0	1	1	1	0	0

Results

The selection process for the studies included for full review is shown in the Figure, the PRISMA flow diagram. From the 5 databases, a total of 176 published articles were identified. After duplicates were excluded there were 136 left for screening. 100 were eliminated on a screening of titles and abstracts. Reading full text articles the researchers eliminated another 26 because they failed to meet all inclusion criteria (Figure). Highly relevant studies by Lord's group[17,20] were excluded because the experimental and control groups were recruited from different populations. Studies of populations with osteoarthritis by Hinman et al[21] and Lund et al[22] were excluded because the samples recruited were not exclusively elderly (over 50 years and over 40 years respectively). There were several Japanese studies of aquatic exercise for balance, but few of these were comparing aquatic exercise with equivalent land exercise or a control. Kaneda et al[23] compared normal aquatic exercise with deep water running, Katsura et al[24] compared aquatic exercise with aquatic exercise using resistance splints, and Sato et al[25] compared the effects of weekly with biweekly aquatic exercise sessions. Additional recent studies by Bergamin et al,[7] Hosseini et al[26] and Tsourlou et al[27] were added to the study following hand searching of article reference lists and a personal recommendation although they had not featured in any of the database searches. The final thirteen studies are listed in Table 1. Of the 13 meeting all inclusion criteria 3 were from North America, 2 from Australasia, and one each from South Korea, Israel, Greece, Italy and Brazil. Of the remaining 3 studies from Iran, 2 were articles presenting different outcome measures from the same study.[28-29] Most of the studies were looking at healthy elderly participants, but 3 studies were limited to groups featuring particular skeletal pathology: Arnold et al[5] looked at women with osteoporosis, Arnold and Faulkner[30] and Hale et al[31] recruited elderly people with varying degrees of lower limb arthritis.

Assessment of Quality

The assessment of quality using the Downs and Black checklist[19] is shown in Table 2. Studies by Arnold and colleagues,[5,30] Avelar et al,[32] Devereux et al,[33] Elbar et al,[6] and Hale et al[31] all scored well on the Downs and Black checklist.[19] In contrast the studies by Hosseini and colleagues[26,28] were lacking in various aspects of both reporting (such as population characteristics, adverse events and whether there were any drop outs during the study), and aspects relating to internal validity (in particular relating to blinding of assessors and being aware of confounders). The studies by Simmons and Hansen[10] and Devereux et al[33] did not blind assessors. The study by Kim and O'Sullivan[34] was a much smaller study than the others, and presented various problems relating to randomization and measurement—in particular the global measure of balance was not explained. The vast majority of studies made their postintervention measurements of balance function in the week after the intervention finished with no long-term follow up. The only studies to include long-term follow-up measures were those by Elbar et al[6] 12 week after the 12 week intervention had finished, by Hosseini et al[26] and by Simmons and Hansen.[10] In general, studies presented results in terms of mean scores and standard deviations, although the study by Avelar et al[32]

Table 2. Extended

Checklist (cont.)														
Internal Validity-Bias							Internal Validity-Confounders						Power	
14	15	16	17	18	19	20	21	22	23	24	25	26	27	
Subjects blind to intervention	Blind assessors	Data dredging	Same length of follow up	Appropriate Statistical tests	Compliance with the intervention	Accurate outcome measure	Control recruited same	Recruit-ment at same time	Randomized allocation	Concealed random-ization	Adjustment for confounders	Subjects lost to follow up	0-5	Total
0	1	1	1	1	0	1	1	0	1	0	1	1		22
0	1	1	1	1	1	1	0	0	1	0	1	1	✓	22
0	1	1	1	1	1	1	1	1	1	0	0	1		21
0	0	1	0	1	1	1	0	0	1	0	1	1		17
0	0	1	1	1	1	1	1	1	1	0	0	1		22
0	1	1	1	1	1	1	1	0	1	1	1	1	✓	22
0	1	1	1	1	0	1	1	1	1	0	1	1	✓	23
0	0	1	1	1	0	1	1	1	1	0	0	0		14
0	0	1	1	1	0	1	1	1	1	0	0	0		13
0	0	1	1	1	0	1	1	1	1	0	0	0		13
1	0	1	1	0	0	0	0	0	1	0	1	1		13
0	0	1	1	1	0	1	1	1	1	0	0	0		18
0	0	1	1	1	0	1	0	0	1	0	1	1		17

only presented the group results in histogram form without the mean scores and indicators of spread around the mean.

Study Findings

The overall findings of the studies in this review comparing aquatic exercise to a control group (all of them) were that participants in the aquatic exercise group scored better than those in the control group on measures of balance.[6,7,10,26,27,28,32,33] The 3 well-constructed studies which looked at groups with arthritis or osteoporosis were not so conclusive.[5,30,31] In the more reliable studies that compared aquatic exercise with land-based equivalents[7,10,32] there was very little evidence that aquatic exercise is more effective. All these findings need to be assessed in the context of multiple deficiencies in the research as presented below (Table 3).

The features of the different studies, including the numbers of participants, the divisions into control and comparison groups, the outcome measures used, and the reported findings, are presented in Table 4. A total of 545 participants were recruited to the 13 studies of aquatic exercise therapy compared to a control, and of these 458 participants were measured at postintervention. Because of the heterogeneous nature of the studies, of the participants, and of the outcome measures used, it is not possible to create a large single group on which to reapply statistical tests. A smaller group of 4 studies also had a comparison group with land based exercises. Two hundred twenty-five participants were recruited for these, of whom 164 were measured at postintervention follow up. The aquatic exercises in different studies appear to be fairly similar although there were some differences in emphasis. For example, Avelar et al[32] looked at the effect of endurance exercises reflecting a belief that poor balance in the elderly is in part a postural endurance problem. On the other hand Elbar et al[6] included specific perturbation exercises, in the belief that balance function is a skill that must reflect practice of rapid stepping in response to perturbations.

Dosage of therapy tested varied between studies. Most sessions in the pool were 40-60 min, although the study by Hale et al[31] began with 20 min sessions and gradually built up their length. Five studies used a 3 times a week protocol[5,26,27,28,29,34] while the rest used a treatment dosage of twice a week. The length of the treatment regime ranged from only 5 weeks[6] to 24 weeks.[7,27]

In their measures of balance, several studies included a measure of walking speed or stamina (3 studies), or of walking incorporated into function as the Timed Up and Go test (6 studies), as well as something more specific to balance. The measures of balance included the Berg Balance Scale (4 studies), Step Test (3 studies), 30 second Chair Stand test (3 studies), and Functional Reach (2 studies). The choice of these different tests in some part reflects the differing abilities of the sample groups recruited, and this can be seen in the range of scores for a particular test like the Berg Balance test. Mean scores for the Berg (maximum possible score 56) varied from preintervention means for groups in the Arnold and Faulkner[30] study of 29.3-31.1 to mean scores in the study by Avelar et al[32] of ca 48.2-ca 51.0 (estimates from

Table 3. Summary of 13 Empirical Studies

Author	Study Design	Number of Subjects (no. Starting the Study)	Intervention and Control Groups				Measurement Points (Weeks)	Outcome Measures for Balance and Gait
Arnold et al[15]	RCT	43 (68)	WBE n = 11 (50m*3pw)*20w	LBE n = 10 (50m*3pw)*20w	Control n = 22 (no exercise waiting list)		0,20	Functional reach test Backward tandem walk 30s chair stand Self-paced walk velocity
Arnold & Faulkner[30]	QRT	61 (79)	WBE+EDU n = 23 [(45m*2pw)+(30m*1pw)]*11w	WBE n = 19 (45m*2pw)*11w	Control n = 19		0,11	BBS 6-min walk 30s chair stand TUG, ABC
Avelar et al[32]	RCT	36 (46)	WBE n = 12 (40m*2pw)*6w	LBE n = 14 (40m*2pw)*6w	Control n = 10		0,6	BBS, DGI Tandem gait Gait Velocity
Bergamin et al[17]	QRT	53 (59)	WBE n = 17 (60m*2pw)*24w	LBE n = 17 (60m*2pw)*24w	Control n = 19		0,24	Sit and reach 8-foot Up and Go
Devereux et al[33]	RCT	47 (50)	WBE n = 23 (60m*2pw)*10w		Control n = 24		0,10	Step test Falls Efficacy Scale
Elbar et al[6]	RCT	34 (35)	WBE n = 17 (40m*2pw)*12w Control n = 17		Control n = 18 (40m*2pw)*12w WBE n = 17		0,12,24	Voluntary Step Execution Test CoP parameters during quiet standing, EO & EC
Hale et al[31]	RCT	35 (39)	WBE n = 20 (20-60m*2pw)*12w		Control n = 15		0,12	PPA Step test TUG, ABC
Hosseini et al[26]	QRT	30 (30)	WBE n = 15 (60m*3pw)*8w		Control n = 15		0,8,12,14,16	Chair stand TUG, BBS
Hosseini et al[28]	QRT	45 (45) (same group as Jalili 2011)	WBE n = 15 (60m*3pw)*8w	WBVT n = 15 (30m*3pw)*8w	Control n = 15		0,8,12,14,16	BBS
Jalili[29]	QRT	45 (45) (same group as Hosseini 2011c)	WBE n = 15 (60m*3pw)*8w	WBVT n = 15 (30m*3pw)*8w	Control n = 15		0,8,12,14,16	TUG Chair stand
Kim and O'Sullivan[34]	RCT	15 (20)	WBE n = 8 (60m*3pw)*12w		Control n = 7		0,12	Balance measure unclear; Kinetics after a perturbation during gait
Simmons and Hansen[10]	QRT	32 (52)	WBE n = 10 (45m*2pw)*5w	LBE n = 5 (45m*2pw)*5w	WS n = 10 (45m*2pw)*5w	LS n = 7 (45m*2pw)*5w	0,1,2,3, 4,5,48	Functional Reach Test
Tsourlou et al[27]	QRT	22 (22)	WBE n = 12 (60m*3pw)*24w		Control n = 10		0,24	TUG Sit and reach

Abbreviations: ABC: Activities and Balance Confidence questionnaire, BBS: Berg Balance Scale, CoP: Centre of Pressure, DGI: Dynamic Gait Index, EC: Eyes Closed, EO: Eyes Open, LBE: Land-based Exercises, LS: Land sitters, m: minutes, N: Numbers, PPA: Physiological Profile Assessment, pw: per week, QRT: Quasi-randomized trial, RCT: Randomized controlled trial, s: seconds, TUG: Timed Get-up and Go test, w: weeks, WBE: Water-based exercises, WBE+EDU: Water-based exercises combined with education, WBVT: Whole body vibration, WS: Water sitters, 6-min walk: Six minute walk test histograms provided). The sample recruited by Avelar's[32] group was evidently more functionally effective than that recruited in the other study.

Measurement of outcomes was performed in all studies pre- and postintervention. One study monitored balance performance of participants at additional interim stages in the study.[10] Long-term follow up was performed in few studies.[10,26,28,29] Of these, none provided blinded assessors.

Discussion

The overall findings of most studies comparing aquatic exercise to a control group (all of the included studies made this comparison) were that participants in the aquatic exercise group scored better than those in the control group on measures of balance.[6,7,10,26,27,28,32,33] This tallies with the findings of the Cochrane review of interventions for preventing falls in the elderly, which found clear evidence in support of exercise programs including balance and strength training.[1] The 3 well-constructed studies which looked at groups with arthritis or osteoporosis were not so conclusive.[5,30,31]

In studies where aquatic exercise was compared to land exercise the findings were more variable. The overall findings of the better executed studies in this sample are not uniformly favorable to aquatic exercise. Of the 4 studies with blinded assessors Arnold et al[5] showed very little difference between the group of women with osteoporosis doing aquatic exercise and those doing land exercise on 2 outcome measures, although backwards tandem walk showed a statistically significant benefit from the aquatic exercise. There were no significant differences in the performance of the aquatic exercise and land-based exercise groups in the studies by Avelar et al,[32] Simmons and Hansen,[10] and Bergamin et al.[7] In other words, there is very little evidence that aquatic exercise is more effective than a land-based equivalent.

On the other hand there is some evidence that there are more adverse events associated with land-based exercise, particularly aggravation of joint symptoms in populations with arthritis or osteoporosis. In the study by Arnold et al[5] 52% of the land-exercise group reported exacerbation of symptoms, but only 29% in the aquatic exercise group.

The articles reviewed looked at the population of interest, the healthy elderly over 60 years. Overall, some 458 participants started the treatment or control arms of the included trials. However, there was some heterogeneity in the samples recruited. Any sample of the healthy elderly population is likely to include people who have minor ailments and conditions associated with old age. In a study by Lord et al,[17] a full table of possible confounders reveals that the samples undergoing aquatic therapy and the control group both included people who complained of self-diagnosed arthritis, high blood pressure, angina, foot problems, and controlled diabetes. More than 60% of each group were taking more than 3 medications. Most of the (more recent) studies included in this review failed to provide such a full break-down of the health status of the elderly participants, revealing only that they were independently living in the community, and that they had none of the conditions precluding participation in aquatic therapy. Some of the studies limited themselves to a subset of the population with arthritis or osteoporosis.[5,30,31] In the light of the probable presence within many of the other groups of participants with minor concentrations of arthritis the authors decided to include these trials in the review population.

The measures selected in different studies reflected the authors' assumptions on the causes of poor balance which they were trying to rectify. Thus, the expressed philosophy of an ineligible study by Douris et al[35] was that poor balance was a function of weakness in certain muscle groups, and therefore the outcomes selected were muscle strength indicators, as well as the Berg Balance Scale. Four of the selected studies used the Berg Balance Scale, but the nature of this scale means that it may not be the best tool to monitor changes over time. It combines 14 ratings using 0-5 point ordinal scales for 14 different tasks, and may therefore conceal ceiling effects. The changes in scores were in the range of one point,[30] 3.5 points,[32] and 3.5 points.[26,28] However, a study examining the metrics of the Berg Balance Scale suggest that a change of about 6 points is needed to be 90% confident of change.[36] Another such study calculated that for 95% confidence the minimum detectable change score would have to be up to 7 points for people scoring within the range 25-34, 5 points for those scoring between 35 and 44, and 4 points for those scoring 45-56.[37] Effect sizes in the better studies were smaller than this. Calculations of effect sizes from the studies using the Berg varied from a change of about 0.29 of the mean SD in Arnold's study[5] to an improbable 1.93 of the mean SD for the water exercise group in the less well conducted study by Hosseini et al.[26] (Avelar et al[32] did not provide sufficient figures to allow calculation of effect sizes.) Tests such as the walking tests, the Functional Reach test and the Step Test are perhaps more sensitive to change, even though they do not cover the same breadth of balance tasks.

Further research is certainly required on this topic. The standard of the studies reviewed above makes it imperative to recommend some minimum standards for future research. Aquatic exercise must be compared to equivalent exercise on land. Assessment must be made by assessors blinded to group allocation. The length of treatment regime should preferably be at least 8 weeks, since studies of a smaller duration may only focus on short-term reversible neural adaptation.[38] Follow-up assessment is necessary to provide evidence of any benefit over the long-term. It should be normal practice to provide both point scores and the 95% confidence intervals. The effect sizes found in the better conducted trials were small or non-significant,

Table 4. Results of Reviewed Studies

Author	Outcome Measures for Balance and Gait	Pre- / Postmeasures (± SD) [95%CIs] of Balance and Gait for Water-based Exercise Groups (WBE), Land-based Exercise Groups (LBE) and Control Groups			Author Reported Findings
Arnold et al[5]		WBE	LBE	Control	• WBE group showed significant improvement in FRT and BTW compared to LBE group; • No significant differences between exercise and control groups
	Functional reach test (cm)	37.7 ± 6.6/39.0 ± 4.9	37.6 ± 6.3/39.6 ± 5.5	38.3 ± 6.3/40.8 ± 5.5	
	Backwards tandem walk	3.1 ± 2.2/2.5 ± 1.8 (no. of errors)	3.4 ± 2.3/3.5 ± 2.4 (no. of errors)	3.3 ± 2.3/2.9 ± 2.4 (no. of errors)	
	60s chair stand (no. stands)	31.7 ± 10.5/34.5 ± 10.5	26.9 ± 8.8/29.9 ± 8.4	29.8 ± 9.0/31.9 ± 11.3	
	Self-paced walk velocity (m/s)	1.3 ± 0.3/1.3 ± 0.3	1.3 ± 0.3/1.3 ± 0.3	1.3 ± 0.3/1.4 ± 0.2	
Arnold and Faulkner[30]		WBE + Education	WBE	Control	• WBE+Education group showed significant improvement in number of chair stands compared to other groups; • Similar trends for TUG, 6MW
	Modified BBS (/36)	30.4 ± 3.8/31.4 ± 3.2	29.3 ± 5.2/30.5 ± 5.1	31.1 ± 2.7/30.9 ± 3.8	
	6-min walk (m)	355.2 ± 93.9/398.5 ± 89.3	357.4 ± 118.1/371.9 ± 136.9	352.3 ± 111.3/ 352.6 ± 123.5	
	30s chair stands (no.)	7.6 ± 3.0/9.1 ± 2.8	6.9 ± 4.3/7.5 ± 3.9	7.5 ± 3.0/8.1 ± 2.6	
	TUG (s)	14.9 ± 5.6/12.6 ± 3.9	15.8 ± 9.1/15.1 ± 9.5	14.3 ± 6.7/14.5 ± 7.1	
Avelar et al[32]		WBE	LBE	Control	• Both exercise groups showed significant improvement compared to control group on BBS & DGI; • NB scores derived from graph only
	BBS (score /56)	51.1/54.5 + 6.7%	50.5/54.0 + 6.9%	48.2/48.5 + 0.6%	
	DGI (score /24)	20.5/23.5 + 14.6%	20.5/23.0 + 12.2%	17.5/18.0 + 2.8%	
	Tandem gait (no. paces)	6.2/8.7	6.0/7.9	5.0/6.1	
	Gait Velocity (m/s)	1.65/1.75	1.75/2.1	1.75/1.70	
Bergamin et al[7]		WBE	LBE	Control	• Statistically significant improvements for exercise groups, greater in the WBE group
	Sit and reach (cm)	3.2 ± 7.3/13.08 ± 6.77	5.3 ± 12.2/13.53 ± 11.51	8.9 ± 7.8/10.37 ± 7.62	
	8-foot Up and Go (s)	5.57 ± 1.21/4.49 ± 0.76	6.08 ± 2.06/5.31 ± 2.08	5.11 ± 0.79/5.28 ± 1.02	
Devereux et al[31]		WBE	Control		• WBE group improved significantly more on Step Test than Control group; • No significant difference on modified falls efficacy scale
	Step test left (no. of steps)	13.0 ± 3.6/15.6 ± 3.2	15.6 ± 3.4/15.6 ± 3.3		
	Step test right(no. of steps)	13.3 ± 2.8/15.8 ± 3.4	15.4 ± 3.3/15.8 ± 3.3		
	mod. Falls Efficacy Scale	9.9 ± 1.8/10.0 ± 1.4	10.0 ± 0.4/10.0 ± 0.0		
Elbar et al[8]		WBE period	Control period		• Significantly greater improvement for tap to Foot Contact time during WBE phases; • Mediolateral sway improved during WBE; • Anterior-posterior sway showed no differences;
	Tap to foot contact (m/s)	Gp A 838.1 ± 149/705.4 ± 110 Gp B 749.8 ± 131/691.7 ± 110	Gp A 705.4 ± 110/ 697.5 ± 111 Gp B 775.2 ± 184/749.8 ± 131		
	CoP in standing (ML sway) (mm)	Gp A 36.6 ± 9/33 ± 9.1 Gp B 31.5 ± 9.3/25.8 ± 12.8	Gp A 33 ± 9.1/38.6 ± 8.4 Gp B 35.8 ± 8.3/31.5 ± 9.3		
Hale et al[15]		WBE	Control		• No significant differences between WBE & Control groups; • Both WBE and Control groups showed significant improvement on Step Test
	PPA	1.5 [0.91-2.05]/1.2 [0.58-1.75]	1.3 [0.70-1.20]/0.6 [0.08-1.19]		
	Step test left (no. of steps)	9.7 [8.65-10.74]/12.0 [10.58-13.42]	10.6 [8.63-12.56]/11.4 [9.90-12.81]		
	Step test right (no. of steps)	10.1 [8.96-11.21]/12.14 [10.81-13.48]	10.9 [8.74-12.91]/11.07 [9.37-12.77]		
	TUG (sec)	11.0 [9.68-12.39]/10.1 [8.80-11.38]	10.7 [7.60-13.76]/10.7 [7.26-14.18]		
	ABC (total=100%)	64.2 [55.64-72.83]/67.0 [55.28-75.77]	66.4 [55.81-76.91]/66.7 [55.99-73.38]		
Hosseini et al[24]		WBE	Control		• Significant improvements in all tests in WBE group, but not for Control group; • Differences mostly maintained over follow - up period
	5 Chair stand (s)	14.30 ± 1.16/12.27 ± 1.31	13.97 ± 1.20/13.84 ± 1.16		
	TUG (s)	7.88 ± 0.23/6.75 ± 0.38	7.66 ± 0.28/7.59 ± 0.52		
	BBS	48.66 ± 1.91/52.13 ± 1.76	48.93 ± 1.75/49.13 ± 1.92		
Hosseini et al[28]		WBE	WBVT	Control	• These 2 papers present the same results for WBE and Control groups as are reported in Hosseini et al[24] • No significant difference between WBE and WBVT groups
	BBS	48.66 ± 1.91/52.13 ± 1.76	48.40 ± 2.09/51.66 ± 1.87	48.93 ± 1.75/49.13 ± 1.92	
Jalili[29]		WBE	WBVT	Control	
	TUG	7.88 ± 0.23/6.75 ± 0.38	7.80 ± 0.31/6.72 ± 0.24	7.66 ± 0.28/7.59 ± 0.52	
	5 Chair stand (s)	14.30 ± 1.16/12.27 ± 1.31	13.83 ± 1.11/12.41 ± 1.26	13.97 ± 1.20/13.84 ± 1.16	

Table 4. Continued

Author	Outcome Measures for Balance and Gait	Pre - / Postmeasures (± SD) [95%CIs] of Balance and Gait for Water - based Exercise Groups (WBE), Land - based Exercise Groups (LBE) and Control Groups				Author Reported Findings
Kim and O'Sullivan[14]		WBE		Control		• WBE showed significant improvement in balance measurement • WBE group showed increased joint moment in response to perturbation during gait
	Balance measure (unclear) (s)	2.41 ± 2.29/3.14 ± 1.5		6.8 ± 4.71/4.77 ± 3.85		
	First stride time after 10cm drop during gait (s)	1.10 ± 0.21/0.84 ± 0.06		0.84 ± 0.06/0.89 ± 0.11		
Simmons and Hansen[10]		WBE	LBE	WS	LS	• Both WBE and LBE groups showed significant improvements in FRT; • No significant improvements in Controls
	Functional Reach Test (cm)	21.6 ± 5.3/34.0 ± 4.1	23.1 ± 2.8/ 28.7 ± 3.8	21.1 ± 3.8/ 24.4 ± 3.3	22.4 ± 2.5/23.6 ± 1.8	
Tsourlou et al[17]		WBE		Control		• WBE group showed significant improvement in TUG (19.8%) and Sit and Reach (11.6%)
	TUG (s)	6.35 ± 0.3/5.09 ± 0.2 (-19.8%)		6.31 ± 0.3/6.23 ± 0.3 (-1.2%)		
	Sit and reach (cm)	21.15 ± 0.3/23.60 ± 1.8 (+11.6%)		22.56 ± 2.4/22.87 ± 2.4 (-2.7%)		

Abbreviations: 6MW = Six minute walk test; ABC = Activities and Balance Confidence questionnaire; AP = anterior-posterior; BBS: Berg Balance Scale; BTW = backward tandem walk; CoP = Centre of Pressure; DEXA = dual energy X-ray absorptiometry; DGI = Dynamic Gait Index; FRT = Functional Reach Test; GP A and B = group A and B; LBE = Land-based Exercises; LS = Land sitters; M = meter; M & F = Male and female; mFES = modified falls efficacy scale; ML = mediolateral ; OA = osteoarthritis; PPA: Physiological Profile Assessment; TUG: Timed Up and Go; WBE: Water-based exercise; WBVT: Water-based exercise with vibration therapy; WS = Water sitters

but this may have been due to small sample sizes. Post hoc power calculations indicated that much greater numbers of participants were needed (60-100) for significant differences to be detected.[5]

There is a specific need for research to assess the effectiveness of particular approaches to aquatic therapy such as Watsu, Ai Chi, and Bad Ragaz for improving balance in the elderly. Currently there are no well-conducted studies looking at the effectiveness of these approaches.

Conclusion

In conclusion, there is evidence that aquatic exercise has positive effects on balance in the elderly, but there is little evidence at present that it is any more effective than equivalent land-based exercise programs. Further research with larger numbers is required. However, there is some evidence that people who are at risk of joint inflammation, or who have fear of falling, may do better in water-based programs, in that there are fewer instances of adverse events.

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