



## Research

## Aquatic exercise improves motor impairments in people with Parkinson's disease, with similar or greater benefits than land-based exercise: a systematic review

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## KEY WORDS

Parkinson's disease  
Hydrokinesitherapy  
Rehabilitation  
Balance  
Quality of life

## ABSTRACT

**Questions:** What are the effects of aquatic exercise on disease severity, (non-)motor impairments, activity performance, fear of falling, and quality of life in people with Parkinson's disease (PD)? Does aquatic exercise have greater effects on these outcomes than other forms of exercise in people with PD? **Design:** Systematic review and meta-analysis of randomised controlled trials. **Participants:** People with idiopathic PD. **Intervention:** Supervised aquatic exercise programs  $\geq 2$  weeks. **Outcomes measures:** The primary outcomes were disease severity, motor impairments, activity performance, and fear of falling. The secondary outcomes were non-motor impairments and quality of life. **Results:** Of the 129 identified records, seven trials met the inclusion criteria and six were meta-analysed (159 participants). One trial assessed the effect of aquatic exercise compared with control and found a significant improvement in the Unified Parkinson's Disease Rating Scale Part III (MD  $-4.6$ , 95% CI  $-7.5$  to  $-1.7$ ) in favour of aquatic exercise. Six studies compared aquatic exercise with land-based exercise after intervention (mean 7.2 weeks of training (SD 2.2); 159 participants). The effect of aquatic exercise was superior to land-based exercise on the Berg Balance Scale (MD 2.7, 95% CI 1.6 to 3.9), the Falls Efficacy Scale (MD  $-4.0$ , 95% CI  $-6.1$  to  $-1.8$ ) and the 39-item Parkinson's Disease Questionnaire (MD  $-6.0$ , 95% CI  $-11.3$  to  $-0.6$ ), with no other significant effects identified. The significant benefit on the Berg Balance Scale was maintained at the follow-up assessment (MD 6.3, 95% CI 2.1 to 10.5, 54 participants). **Conclusion:** Aquatic exercise improves motor impairments in people with PD significantly more than no intervention. It also has slightly to moderately greater benefits than land-based exercise on balance capacity, fear of falling, and health-related quality of life. On other outcomes, the benefits of aquatic exercise are similar to those of land-based exercise. **Trial registration:** PROSPERO CRD42017077370. [Cugusi L, Manca A, Bergamin M, Di Blasio A, Monticone M, Deriu F, Mercuro G (2019) Aquatic exercise improves motor impairments in people with Parkinson's disease, with similar or greater benefits than land-based exercise: a systematic review. *Journal of Physiotherapy* ■-■-■]

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## Introduction

Parkinson's disease (PD) is a progressive, neurodegenerative movement disorder characterised by the motor symptoms bradykinesia, tremor, rigidity, and postural instability. These are commonly associated with non-motor disturbances, neurobehavioural symptoms and reduced quality of life.<sup>1</sup>

Exercise is currently recommended as an additional strategy to manage PD-induced disability and is a key component of rehabilitation programs for people with PD.<sup>2-4</sup> Systematic reviews of randomised controlled trials involving exercise have extensively investigated the effects of conventional exercise-based protocols, including aerobic and strength training programs, in people with

PD.<sup>4-9</sup> These reviews suggest that conventional exercise training positively affects disease severity, motor impairments and activity performance, in addition to non-motor impairments, social dimensions and the quality of life of participants.<sup>4-9</sup>

Recent studies have observed promising health effects following less conventional forms of exercise, including dance,<sup>10</sup> Tai Chi,<sup>11</sup> Nordic walking,<sup>12,13</sup> and other complementary therapies<sup>14,15</sup> to counteract the functional deterioration induced by PD.

Aquatic exercise is another form of non-conventional exercise that has been growing in popularity in the context of neuro-rehabilitation.<sup>16</sup> The aquatic setting offers specific mechanical advantages due to the hydrostatic and hydrodynamic principles of buoyancy, viscosity and drag.<sup>16</sup> Buoyancy offloads weight-bearing,<sup>17</sup>

**Box 1. Inclusion criteria.****Design**

- Randomised trial
- Published in English

**Participants**

- People with idiopathic Parkinson's disease

**Intervention**

- Aquatic exercise
- Exercise program duration  $\geq 2$  weeks
- Supervision provided by a physiotherapist or other exercise professional
- No co-interventions alongside the exercise unless they were equal in both groups

**Outcome measures**

- Primary outcomes: disease severity, motor impairments, activity performance, and fear of falling
- Secondary outcomes: non-motor impairments and quality of life

**Comparisons**

- Aquatic exercise versus control (ie, no exercise intervention)
- Aquatic exercise versus other (eg, land-based) exercise

which, when combined with the warmth of the water, has been associated with decreased pain and stiffness.<sup>18,19</sup> The viscosity of water is an exceptional source of natural resistance and viscous drag can facilitate different motor training tasks<sup>20</sup> by providing an accommodating resistance for muscle strengthening.<sup>17</sup> These features of the aquatic setting allow some people with postural instability, high risk of falling, leg weakness and gait disturbance to exercise successfully when this is unfeasible or unsafe on land.<sup>21,22</sup>

Due to its ability to enhance functional mobility whilst also being enjoyable,<sup>23,24</sup> aquatic exercise has become a very popular form of physical training in the management of neurodegenerative disorders.<sup>25–28</sup> Previous systematic reviews<sup>25–28</sup> have reported that aquatic exercise is safe and improves aspects of activity performance, quality of life and balance in people with PD, although safety criteria were generally under-reported.<sup>28</sup> However, these reviews had various limitations, such as the inclusion of non-randomised trials and failure to conduct any meta-analysis. Therefore, effects of aquatic exercise in people with PD still need to be summarised rigorously, given how frequently it is used in the management of PD-related disability.

Therefore, the research questions for this systematic review and meta-analysis were:

1. What are the effects of aquatic exercise on disease severity, (non-) motor impairments, activity performance, fear of falling, and quality of life in people with PD?
2. Does aquatic exercise have greater effects on these outcomes than other forms of exercise in people with PD?

**Methods**

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and flow chart diagram were used as a reporting structure for this systematic review.<sup>29,30</sup>

**Identification and selection of studies**

The following databases were systematically searched: Physiotherapy Evidence Database (PEDro), PubMed, Scopus, and the Cochrane Central Register of Controlled Trials (CENTRAL). The search combined Medical Subject Headings, keywords and matching synonyms relevant to the intervention (eg, 'aquatic-based exercise', 'water-based exercise', 'hydrokinesitherapy', 'balneotherapy', 'water

training', 'aquatic therapy') and the population ('Parkinson's disease'). The detailed search strategy for each database is presented in Appendix 1 on the eAddenda. Each database was searched from the earliest available record up to December 2017. Only randomised controlled trials published in English-language<sup>31</sup> journals were selected, and the references of all the included articles were checked for further relevant publications.

The initial search was undertaken by one of the authors (LC). The titles and abstracts of the retrieved studies were then independently assessed by two authors (LC and MB); duplicates and records that were clearly ineligible were excluded at this stage. When the title or abstract presented insufficient information to determine eligibility, the full-text papers were evaluated. Based on the information presented in the full manuscripts, eligible studies were included in the systematic review. In cases of disagreement, consensus was reached by discussion and, if necessary, a third author (AM) contributed to the final decision. Studies were included if they satisfied the inclusion criteria based on the Patient, Intervention, Comparison, Outcome (PICO) model<sup>32</sup> shown in Box 1. No co-interventions alongside the exercise were allowed unless they were equal in both groups.

**Assessment of characteristics of studies***Risk of bias and quality of evidence*

The included studies were assessed independently by two authors (LC and MB) for methodological quality and risk of bias, employing the Physiotherapy Evidence Database (PEDro) scale.<sup>33</sup> A trial with a score  $\leq 4$  was considered of poor methodological quality. Disagreements between the two authors were resolved by discussion. If consensus could not be reached, a third reviewer was consulted (AM).

The Grading of Recommendation, Assessment, Development and Evaluation (GRADE) system was used to assess the risk of bias among trials for each meta-analysis.<sup>34</sup> The quality level of each body of evidence was downgraded or upgraded from the baseline 'high quality' (given that all studies were randomised controlled trials) according to pre-defined criteria.<sup>35</sup> Quality was downgraded by one level if: most trials scored  $\leq 6$  on the PEDro scale (*Risk of bias*); they reported wide-ranging participant populations or interventions (*Indirectness*); an  $I^2$  statistic  $\geq 50\%$  that could not be explained in sensitivity analyses indicated substantial heterogeneity (*Inconsistency*); large confidence intervals were found (*Imprecision*); and asymmetry of a funnel plot, which was only assessed if  $\geq 10$  trials were included in the meta-analysis (*Publication bias*).<sup>36</sup> Evidence was downgraded two places if most trials scored  $\leq 4$  on the PEDro scale. Lastly, evidence quality was upgraded one place if the effect size was large.<sup>35</sup> The evidence was then ranked into one of four levels: *very low* (the true effect is probably markedly different from the estimated effect), *low* (the true effect might be markedly different from the estimated effect), *moderate* (the authors believe that the true effect is probably close to the estimated effect), or *high* (the authors have a lot of confidence that the true effect is similar to the estimated effect).

*Participants, intervention and outcome measures*

A customised data extraction form was applied to each trial by one author (AM) and the extracted data were checked for accuracy by a second author (LC). The extracted data included information regarding the study design, participants (age, gender, disease severity, On/Off phase), intervention (type of exercise, length of exercise session, frequency of sessions per week, duration of intervention, and supervision of intervention), aquatic setting (pool depth and water temperature), outcome measures, timing of assessments (post-treatment and follow-up), adherence, adverse events, number of dropouts, and the main findings.

Primary outcome data were extracted from each included study if they pertained to disease severity (eg, the Unified Parkinson's Disease Rating Scale (UPDRS) Total score, that ranged from 0 'no symptoms' to 199 'severe symptoms'), motor impairments (eg, UPDRS-III, scoring from 0 to 108), activity performance (eg, Berg Balance Scale, BBS, which assesses balance capacity with scores ranging from 0 to 56, with higher values indicating better balance; or Timed Up and Go test

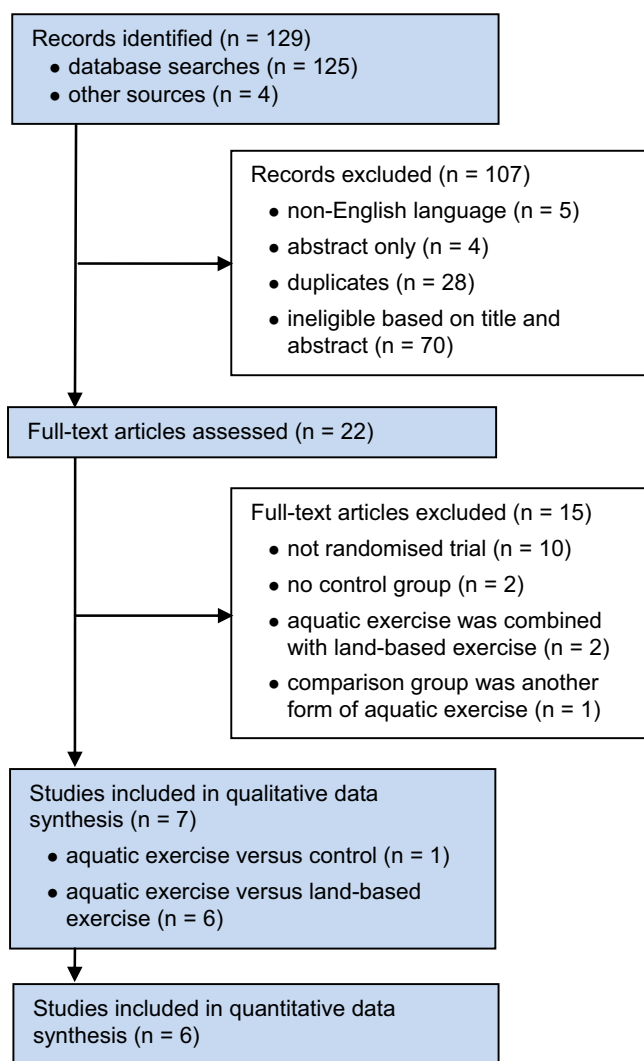


Figure 1. Flow of studies through the review.

to assess functional mobility) and fear of falling (eg, Falls Efficacy Scale, ranging from 16 to 64, with higher scores indicating greater fear of falling). The secondary outcomes were related to non-motor impairments and quality of life (eg, the 39-item Parkinson's Disease Questionnaire, PDQ-39, which assesses PD-specific health-related quality of life, where lower scores reflect better quality of life).

### Data analysis

A meta-analysis was performed if at least two studies reported data for the same outcome measure.<sup>27,28</sup> RevMan software was used to meta-analyse the data, where possible.<sup>37</sup> Raw data (means and SD) were extracted or calculated from other statistics in the paper.<sup>38</sup> In cases of missing data, a formal request was sent to the corresponding author and first author of the study under consideration. When available (or calculable) in the full-text or from the authors, change data were used.<sup>39</sup> To account for potential methodological differences in the assessment and training protocols across studies, a random-effects model was used for all meta-analyses.<sup>40</sup> To allow interpretation of the pooled estimate of an effect, a mean difference with 95% CI was calculated. A weighted mean difference was calculated when pooling data from the same outcome measure, whereas a standardised mean difference was calculated when pooling homogeneous outcome data from similar outcome measures.<sup>41</sup>

Data homogeneity was assessed using the chi-square test and  $I^2$  statistic, where a value  $\geq 50\%$  indicated substantial heterogeneity.<sup>42</sup> In case of heterogeneity exceeding this threshold, sensitivity analyses were conducted to check whether the heterogeneity was caused

by a single study. A leave-one-out approach was performed by removing the outlying study. To this aim, box and whisker plots were constructed to verify whether data of the outlying study were 1.5 times the interquartile range below the first quartile or above the third quartile.<sup>43</sup> Publication bias was planned to be examined through visual inspection of funnel plot asymmetry and the Egger's regression-based method. When outcomes were assessed at multiple time points (post-treatment and follow-up assessment), data from each time point were extracted to be included in separate meta-analyses.

## Results

### Flow of studies through the review

The search strategy identified 129 potentially relevant records, 22 of which were assessed in full text. Seven trials were eligible and were included in the review.<sup>44–50</sup> The reasons for exclusion of other studies are presented in Figure 1. A comprehensive list of the excluded studies with the main reasons for exclusion is presented in Appendix 2 on the eAddenda.

### Characteristics of the included trials

Of the seven trials included in the review,<sup>44–50</sup> one assessed the effect of aquatic exercise compared to usual care.<sup>44</sup> The remaining six trials reported data for the same comparison (aquatic exercise versus land-based exercise) and outcome measures<sup>45–50</sup>; these were therefore included in meta-analyses for the various outcome measures. All contributed data to meta-analyses of post-treatment data; three also presented follow-up results,<sup>45,47,49</sup> which allowed further meta-analyses of data recorded subsequent to the completion of the intervention phase.

### Quality

PEDro scores were downloaded from the PEDro website for five trials<sup>44–47,49</sup> and scored by the authors for the other two trials.<sup>48,50</sup> The PEDro scores ranged from 4 to 8 (mean 6.4, SD 1.3, median 7.0), as presented in Table 1. No trial reported blinding of participants and therapists, while blinding of assessors was reported in three trials.<sup>46,47,49</sup> All seven trials reported data from between-group analyses and provided point estimates and measures of variability for at least one primary outcome. A follow-up assessment was scheduled and reported in all the included trials except one.<sup>43</sup> Intention-to-treat analysis was performed in four studies<sup>44,46,48,50</sup> and allocation was concealed in five studies.<sup>44,46–48,50</sup> Aquatic exercise and control/comparison groups were similar at baseline in all of the included studies except one.<sup>49</sup>

### Participants

The seven included trials were conducted between 2011 and 2018, and involved a total of 187 people with PD. In one study,<sup>46</sup> gender data were not reported (34 participants, 18%). The remaining six trials (153 participants) enrolled 99 males (65%) and 54 females (35%).<sup>44,45,47–50</sup> The mean age of the participants in each trial ranged from 61 to 71 years. Five trials reported data on the duration of PD since diagnosis, ranging from 6 to 9.2 years.<sup>44–47,49</sup> Different ranges of Hoehn and Yahr stages<sup>51</sup> were set in the individual trials as inclusion criteria: from 1 to 3,<sup>44,49</sup> from 2 to 3,<sup>45,48,50</sup> from 2.5 to 3,<sup>46</sup> and up to 3.<sup>47</sup> On average, participants had a mild to moderate degree of disability (from 1 to 3 on the Hoehn and Yahr scale). Four trials stated that participants were in the On phase,<sup>44,46,50</sup> and three in the Off phase of medication.<sup>45,48,49</sup> Four trials clearly reported types and doses of medications used.<sup>46–48,50</sup> Further details are presented in Table 2.

### Interventions

One trial compared aquatic exercise training to a control of usual medical therapy and normal activities of daily living without prescribed exercise (11 versus 10 participants, respectively).<sup>44</sup> The

**Table 1**  
PEDro Scale ratings for the included trials (n = 7).

Trial	Random allocation	Concealed allocation	Groups similar at baseline	Participant blinding	Therapist blinding	Assessor blinding	< 15% dropouts	Intention-to-treat analysis	Between-group difference reported	Point estimates and variability reported	Total (0 to 10)
Carrol <sup>44</sup>	Y	Y	Y	N	N	N	Y	Y	Y	Y	7
Vivas <sup>45</sup>	Y	N	N	N	N	N	Y	N	Y	Y	4
Volpe <sup>46</sup>	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Volpe <sup>47</sup>	Y	Y	Y	N	N	Y	N	N	Y	Y	6
Shahmohammadi <sup>48</sup>	Y	Y	Y	N	N	N	Y	Y	Y	Y	7
Pérez de la Cruz <sup>49</sup>	Y	N	Y	N	N	Y	Y	N	Y	Y	6
Kurt <sup>50</sup>	Y	Y	Y	N	N	N	Y	Y	Y	Y	7

N = no, PEDro = Physiotherapy Evidence Database, Y = yes.

remaining six trials compared aquatic exercise training to land-based exercise training (166 participants).<sup>45–50</sup>

The intervention periods among the included trials had a duration of 4 to 10 weeks (mean 7, SD 2). Different weekly frequencies and session durations of aquatic exercise training were tested in the studies, ranging from 2 to 5 times/week (mean 3.4, SD 1.5) and from 45 to 60 minutes/session (mean 54, SD 8).

Aquatic exercise training consisted of a group class supervised by a physiotherapist and involved a warm-up phase, a central main phase (aerobic/endurance training performed in water) and a cool-down phase. In two studies,<sup>49,50</sup> the central phase of the aquatic exercise training was characterised by a set of Ai Chi exercise movements, which is a form of aquatic exercise used for recreation, relaxation, fitness and physical rehabilitation combining exercises including trunk rotation, standing balance and single-leg balance. Aquatic exercise was conducted in low-depth hydrotherapy pools (range 0.6 to 1.45 m). The water temperature was set at 32 °C in three trials,<sup>44,45,50</sup> and 30 °C in two.<sup>48,49</sup> Water-depth levels and temperature were not reported in two trials.<sup>46,47</sup> Further details are presented in Table 2.

In the one trial (21 participants) that compared aquatic exercise to no prescribed exercise program, both groups continued usual care (medical therapy and normal activities of daily living).<sup>44</sup> In the six trials that compared aquatic exercise to land-based exercise (166 participants),<sup>45–50</sup> the land-based exercise consisted of a physiotherapist-supervised group class mainly comprising aerobic training (walking or stationary cycling), strengthening exercises, calisthenics and stretching exercises. Further details are presented in Table 2.

#### Outcome measures

All trials assessed participants at the end of the intervention period, and three trials then performed a follow-up assessment after a further 17 days,<sup>45</sup> 1 month<sup>49</sup> and 8 weeks.<sup>47</sup> Activity performance was analysed by all the included trials,<sup>44–50</sup> disease severity by two trials,<sup>45,49</sup> motor impairments by five trials,<sup>44,46,47,49,50</sup> fear of falling by two trials,<sup>46,47</sup> quality of life by five trials,<sup>44,46–48,50</sup> and non-motor impairments (pain severity) by one trial.<sup>49</sup> One trial reported adverse events and dropouts during the aquatic exercise training.<sup>47</sup> One participant dropped out due to hydrostatic hypotension and one due to pulmonary disease. The general adherence of participants was described as high in all trials, although it was only clearly reported in two trials<sup>48,49</sup> at 80 and 100%, respectively. Further details are presented in Table 2.

#### Aquatic exercise versus control

One trial compared the outcomes of an experimental group (n = 11) who performed aquatic exercise with a control group (n = 10) who maintained their usual medical therapy and were prescribed no additional exercise.<sup>40</sup> Due to loss to follow-up, data were available for 18 participants. After 6 weeks of aquatic exercise training, the experimental group improved on the UPDRS-III score from a median of 17.5 down to a median of 13 (median difference 4.5), whereas the control group was unchanged (median difference 0.0), which was statistically significant on the Mann-Whitney U test ( $p = 0.01$ ).<sup>44</sup> In

order to provide an indication of the precision around this estimate of the effect of aquatic exercise, we converted the non-parametric data from the original paper (reproduced in Table 3 on the eAddenda) into parametric data using the methods of Hozo et al.<sup>38</sup> The between-group comparison using the parametric data was a mean difference of 4.6 (95% CI 1.7 to 7.5) in favour of the experimental group. There were no significant differences among the remaining outcomes: Freezing of Gait questionnaire, the 10-m walk test with gait analysis, or the PDQ-39. The data for all outcomes are presented in Table 3 on the eAddenda. There were no follow-up assessment points in that study.

#### Aquatic exercise versus land-based exercise

##### Post-intervention

The meta-analyses of the studies that evaluated UPDRS outcomes (Total score, Part-II and Part-III) revealed no significant between-group differences in UPDRS Total score (two studies, 41 participants, MD -0.1, 95% CI -7.7 to 7.5),<sup>45,49</sup> or in UPDRS-II (two studies, 64 participants, MD 0.7, 95% CI -1.2 to 2.5).<sup>46,49</sup> In the meta-analysis of the UPDRS-III data, a trend towards decrease, which failed to reach significance, was observed (four studies, 128 participants, MD -1.1, 95% CI -2.2 to 0.0).<sup>46,47,49,50</sup> These meta-analyses are presented in Figure 2, with a more detailed forest plot available in Figure 3 on the eAddenda.

In the meta-analyses of the studies reporting BBS results, pooled data from five studies (139 participants) revealed a significant between-group difference in favour of aquatic exercise (MD 2.7, 95% CI 1.6 to 3.9).<sup>45–47,49,50</sup> (Figure 4, with a more detailed forest plot available in Figure 3 on the eAddenda). Data pooling from the same five studies that reported Timed Up and Go test results (139 participants) showed excessive heterogeneity ( $I^2 > 50%$ ) across the trials.<sup>45–47,49,50</sup> Sensitivity analyses were therefore conducted, which revealed that the pooled estimate was highly influenced by the study of Kurt et al (2018; 40 participants).<sup>50</sup> This study was removed, employing a leave-one-out approach,<sup>39</sup> resulting in a moderate heterogeneity ( $I^2 = 41%$ ) and no significant between-group difference (four studies, 99 participants after sensitivity analyses; MD -0.8 seconds, 95% CI -2.2 to 0.5).<sup>45–47,49</sup> Figure 5 shows the final forest plot, with more detailed forest plots of before and after exclusion of the outlying trial available in Figure 3 on the eAddenda.

Two studies (58 participants) reported data for the Activities-specific Balance Confidence Scale and Falls Efficacy Scale.<sup>46,47</sup> Meta-analysis of the Activities-specific Balance Confidence Scale results showed excessive heterogeneity ( $I^2 = 71%$ ) across the two trials and no significant between-group difference (MD 6.5, 95% CI -8.9 to 21.9).<sup>46,47</sup> Meta-analysis favoured aquatic exercise for the Falls Efficacy Scale score (MD -4.0, 95% CI -6.1 to -1.8).<sup>46,47</sup> (See Figures 6 and 7, with more detailed forest plots available in Figure 3 on the eAddenda).

Meta-analysis of the data from the four studies that reported quality of life outcomes (assessed by the Parkinson's Disease Quality of Life Questionnaire,<sup>48</sup> and PDQ-39)<sup>46,47,50</sup> showed excessive heterogeneity ( $I^2 > 50%$ ) across the trials.<sup>46–48,50</sup> Sensitivity analyses were therefore performed, which revealed that the pooled estimate was highly influenced by the study of Shahmohammadi et al



**Table 2**  
Detailed characteristics of the included trials (n = 7).

Trial	Participants <sup>a</sup>	Intervention		Outcome measures
		Experimental	Control	
Carrol <sup>44</sup> Ireland	n = 21 Age (y) = 71 Gender = 14 M, 7 F PD duration (y) ≈ 8.7 H & Y = 1 to 3 Phase = On	Aquatic exercise 45 min, 2/wk, 6 wks Water temp (°C) = 32 Depth (m) = 0.60 to 1.30	No change to usual exercise routine	<ul style="list-style-type: none"> <li>• FOGQ</li> <li>• UPDRS-III</li> <li>• 10-m WT with gait analysis (step length, step time, step width)</li> <li>• PDQ-39</li> </ul> Baseline and post-intervention
Vivas <sup>45</sup> Spain	n = 12 Mean age (y) = 67 Gender = 8 M, 4 F PD duration (y) ≈ 6 H & Y = 2 to 3 Phase = Off	Aquatic exercise 45 min, 2/wk, 4 wks Water temp (°C) = 32 Depth (m) = 1.30	Land-based exercise 45 min, 2/wk, 4 wks	<ul style="list-style-type: none"> <li>• UPDRS Total score</li> <li>• BBS</li> <li>• TUG</li> <li>• FRT</li> <li>• 5-m WT with gait analysis (turn time, velocity, cadence and step amplitude)</li> </ul> Baseline, post-intervention, and 17 days later
Volpe <sup>46</sup> Italy	n = 34 Mean age (y) = 67 Gender = NR PD duration (y) ≈ 7.5 H & Y = 2.5 to 3 Phase = On	Aquatic exercise 60 min, 5/wk, 8 wks Water temp = NR Depth = NR	Land-based exercise 60 min, 5/wk, 8 wks	<ul style="list-style-type: none"> <li>• UPDRS-II and III</li> <li>• FES</li> <li>• ABC</li> <li>• BBS</li> <li>• TUG</li> <li>• Postural analysis (COPSwayOE, COPSwayCE at FRT)</li> <li>• PDQ-39</li> </ul> Baseline and post-intervention
Volpe <sup>47</sup> Italy	n = 30 Mean age (y) = 70 Gender = 19 M, 11 F PD duration (y) ≈ 9.2 H & Y ≤ 3 Phase = On	Aquatic exercise 60 min, 5/wk, 8 wks Water temp = NR Depth = NR	Land-based exercise 60 min, 5/wk, 8 wks	<ul style="list-style-type: none"> <li>• UPDRS-III</li> <li>• FES</li> <li>• ABC</li> <li>• BBS</li> <li>• TUG</li> <li>• Postural analysis (cervical/dorsal flexion and angle of lateral inclination of the trunk)</li> <li>• PDQ-39</li> </ul> Baseline, post-intervention and 8 wks later
Shahmohammadi <sup>48</sup> Iran	n = 20 Mean age (y) = 61 Gender = 20 M, 0 F PD duration (y) ≈ NR H & Y = 2 to 3 Phase = Off	Aquatic exercise 60 min, 3/wk, 8 wks Water temp (°C) = 30 Depth = waist deep	Land-based exercise 60 min, 3/wk, 8 wks	<ul style="list-style-type: none"> <li>• Postural analysis (sway range, mean velocity, sway area, mean frequency in a standing position for 90 s)</li> <li>• PDQL</li> </ul> Baseline and post-intervention
Pérez de la Cruz <sup>49</sup> Spain	n = 30 Mean age (y) = 67 Gender = 14 M, 16 F PD duration (y) ≈ 6.5 H & Y = 1 to 3 Phase = Off	Aquatic exercise with aquatic Ai Chi component 45 min, 2/wk, 10 wks Water temp (°C) = 30 Depth (m) = 1.10 to 1.45	Land-based exercise 45 min, 2/wk, 10 wks	<ul style="list-style-type: none"> <li>• UPDRS-I, II, III, IV and Total</li> <li>• BBS</li> <li>• TUG</li> <li>• FTSST</li> <li>• Tinetti Scale</li> <li>• VAS</li> </ul> Baseline, post-intervention, and 1 mth later
Kurt <sup>50</sup> Turkey	n = 40 Mean age (y) = 63 Gender = 24 M, 16 F PD duration (y) ≈ NR H & Y = 2 to 3 Phase = On	Aquatic exercise with aquatic Ai Chi component 60 min, 5/wk, 5 wks Water temp (°C) = 32 Depth (m) = 1.20	Land-based exercise 60 min, 5/wk, 5 wks	<ul style="list-style-type: none"> <li>• UPDRS-III</li> <li>• BBS</li> <li>• TUG</li> <li>• Dynamic balance (antero-posterior index, medio-lateral index, overall balance index)</li> <li>• PDQ-39</li> </ul> Baseline, post-intervention

ABC = Activities-specific Balance Confidence scale, BBS = Berg Balance Scale, COPSwayOE = centre of pressure sway area with open eyes, COPSwayCE = centre of pressure sway area with closed eyes, F = female, FES = Falls Efficacy Scale, FOGQ = Freezing of Gait Questionnaire, FRT = Functional Reach Test, FTSST = Five Times Sit-to-Stand test, H & Y = Hoehn and Yahr scale, M = male, NR = not reported, PD = Parkinson's disease, PDQL = Parkinson's Disease Quality of Life Questionnaire, PDQ-39 = 39-item Parkinson's Disease Questionnaire, QOL = quality of life, TUG = Timed Up and Go test, UPDRS = Unified Parkinson's Disease Rating Scale, VAS = visual analogue scale, WT = walk test.

<sup>a</sup> Age and PD duration are reported as means.

(20 participants).<sup>48</sup> This study was excluded using a leave-one-out approach,<sup>39</sup> which allowed the MD to be calculated, because the other studies all employed the PDQ-39. This resulted in moderate heterogeneity ( $I^2 = 38\%$ ) and a significant between-group difference (MD  $-6.0$ , 95% CI  $-11.3$  to  $-0.6$ ) in favour of aquatic exercise compared to land-based exercise (three studies, 98 participants).<sup>46,47,50</sup> Figure 8 shows the final forest plot, with more detailed forest plots of before and after exclusion of the outlying trial available in Figure 3 on the eAddenda.

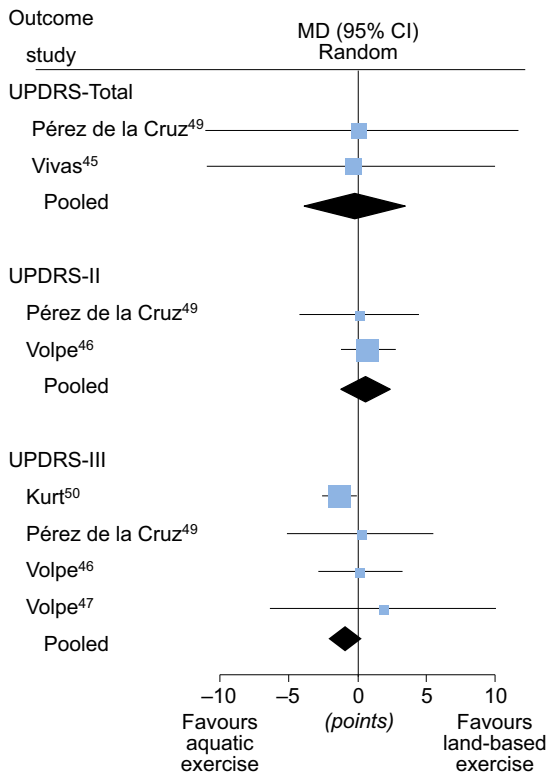
One trial compared the effects of the two training programs on pain severity using a 10-cm visual analogue scale.<sup>49</sup> The aquatic exercise group showed a significant improvement in the visual analogue scale compared to the land-based exercise group at the end

of the intervention period (MD  $-1.2$ , 95% CI  $-2.0$  to  $-0.4$ ) and at the follow-up evaluation (MD  $-1.5$ , 95% CI  $-2.2$  to  $-0.8$ ).<sup>49</sup>

**Follow-up**

The meta-analyses of the studies that evaluated UPDRS outcomes revealed no significant between-group differences in UPDRS Total score (two studies, 41 participants, MD 0.5, 95% CI  $-9.1$  to 10.0),<sup>45,49</sup> or UPDRS-III (two studies, 54 participants, MD 0.8, 95% CI  $-3.5$  to 5.1).<sup>47,49</sup> These meta-analyses are presented in Figure 9, with a more detailed forest plot available in Figure 10 on the eAddenda.

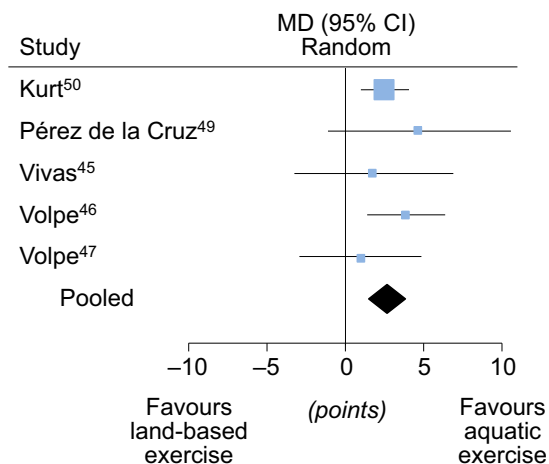
Data pooling from the three studies reporting BBS results (65 participants) showed excessive heterogeneity across the trials ( $I^2 > 50\%$ ).<sup>45,47,49</sup> Sensitivity analyses revealed that the pooled



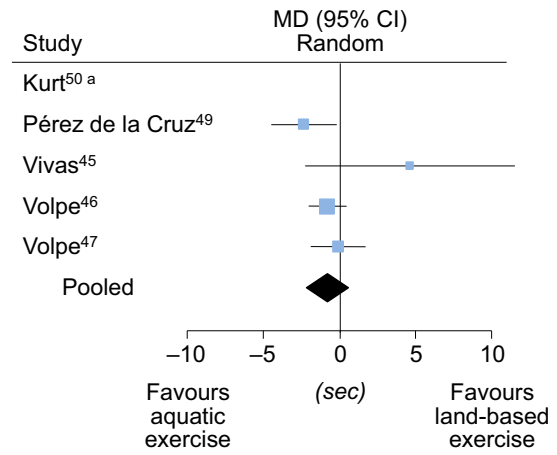
**Figure 2.** Weighted mean difference (95% CI) in the effect of aquatic exercise versus land-based exercise on components of the Unified Parkinson's Disease Rating Scale at the end of the intervention period.

estimate was highly influenced by the study of Vivas et al (11 participants).<sup>45</sup> This study was removed by a leave-one-out approach,<sup>39</sup> resulting in a moderate heterogeneity across the trials ( $I^2 = 30\%$ ). The significant between-group difference favouring aquatic exercise compared to land-based exercise that had been observed at the end of the treatment period was maintained at the follow-up evaluation (two studies, 54 participants after sensitivity analysis, MD 6.3, 95% CI 2.1 to 10.5).<sup>47,49</sup> This result is presented in Figure 11, with a more detailed forest plot available in Figure 10 on the eAddenda.

Similarly, the meta-analysis of the three trials reporting Timed Up and Go test data (65 participants) was non-significant but with excessive heterogeneity ( $I^2 = 65\%$ ). When the outlying study by Perez de la Cruz was omitted, the pooled result remained non-significant (two studies, 35 participants after sensitivity analysis,  $I^2 = 28\%$ , MD 0.9 seconds, 95% CI -2.8 to 4.6).<sup>45,47,49</sup> This result is presented in



**Figure 4.** Weighted mean difference (95% CI) in the effect of aquatic exercise versus land-based exercise on the Berg Balance Scale at the end of the intervention period.



**Figure 5.** Weighted mean difference (95% CI) in the effect of aquatic exercise versus land-based exercise on the Timed Up and Go test at the end of the intervention period. <sup>a</sup> The data from the study by Kurt et al<sup>50</sup> are omitted due to heterogeneity - see main text and eAddenda for details.

Figure 12, with a more detailed forest plot available in Figure 10 on the eAddenda.

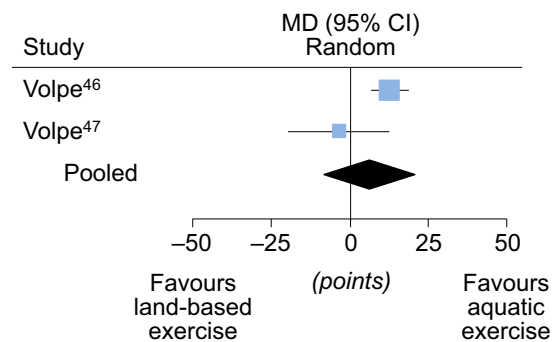
One trial compared the effects of the two training programs on pain severity using a 10-cm visual analogue scale.<sup>49</sup> The significant benefit that this study observed at the end of the treatment period was also present 1 month after the end of the intervention period (MD -1.5, 95% CI -2.2 to -0.8).

**GRADE assessment**

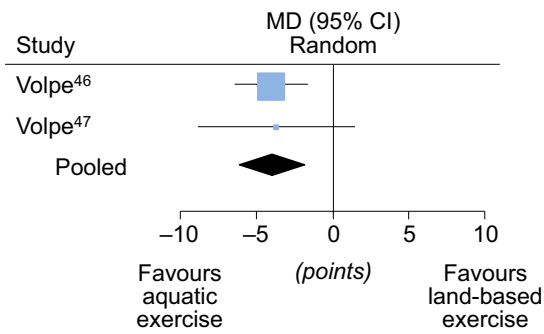
The GRADE assessment of the quality of evidence is summarised in Table 4. All the analysed outcomes were scored as very low to low quality of evidence, except for PDQ-39, which was scored as high, and BBS at the end of the treatment period, which was scored as moderate.

**Discussion**

The first question of this systematic review examined the effects of aquatic exercise in people with PD. Only one randomised trial<sup>44</sup> compared aquatic exercise to usual care and it did not find any statistically significant between-group differences in activity performance and quality of life outcomes except for the UPDRS-III. Based on the Hoehn and Yahr stages, the mean UPDRS-III ranged from a low of 11.2 (SD 4.9) for participants in stage 1 to a high of 35.9 (SD 9.3) for participants in stage 3.<sup>51</sup> Following aquatic exercise training, Carroll et al<sup>44</sup> detected an MD of 4.6 points on the UPDRS-III score. Changes of 2.5 to 5.2 points on the UPDRS-III and 4.5 to 9.1 points on the UPDRS Total score have been previously established by Shulman et al<sup>52</sup> as clinically meaningful differences for these variables.



**Figure 6.** Weighted mean difference (95% CI) in the effect of aquatic exercise versus land-based exercise on the Activities-specific Balance Confidence score at the end of the intervention period.



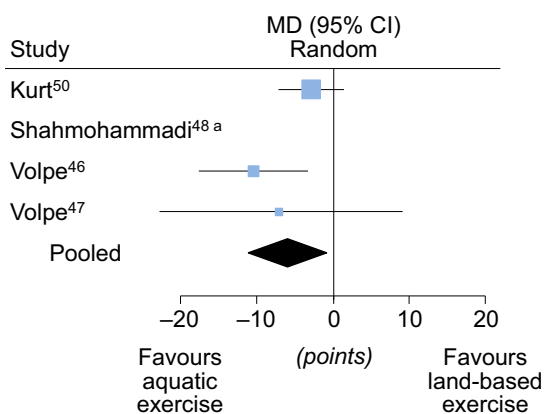
**Figure 7.** Weighted mean difference (95% CI) in the effect of aquatic exercise versus land-based exercise on the Falls Efficacy Scale at the end of the intervention period.

Therefore, we considered the effect of 4.6 points on the UPDRS-III to be a moderately clinically important difference.

Although the effect of aquatic exercise on the UPDRS-III appears clinically important, further evidence from adequately powered trials would be necessary to fully recommend this therapeutic approach. Indeed, the small amount of data from only one trial may have affected the ability to detect significant changes in the other analysed outcomes. Moreover, because land-based exercise is already well established as a beneficial form of rehabilitation, it is undoubtedly more relevant to consider whether aquatic exercise effects are different from those induced by land-based exercise. Accordingly, this review's second question was to establish if aquatic exercise had greater health effects than other forms of exercise in people with PD.

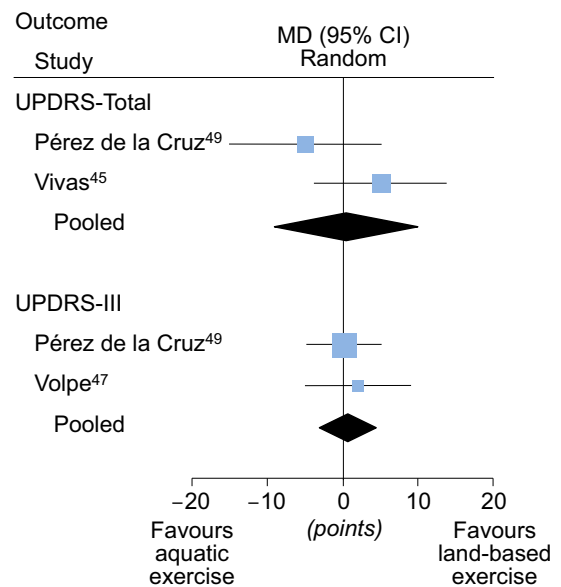
The findings of our meta-analyses showed that aquatic exercise and land-based exercise had similar effects on disease severity, motor impairments and functional mobility, and that aquatic exercise had significantly greater benefit than land-based exercise on the BBS values and Falls Efficacy Scale score. Taken together, these results seem to suggest that aquatic exercise may be particularly helpful in people with PD presenting with specific balance disorders and fear of falling.

No differences between the two interventions were observed in the UPDRS Total score,<sup>45,49</sup> UPDRS-II,<sup>46,49</sup> UPDRS-III,<sup>46,47,49,50</sup> and Timed Up and Go test results.<sup>45-47,49</sup> Furthermore, the 95% CIs around these results were relatively narrow, suggesting that aquatic exercise is as effective as land-based exercise for these outcomes. The UPDRS-III score decreased by an average of 4.4 points from baseline to the post-treatment evaluation both in the aquatic and land-based exercise groups, with a trend towards greater improvement observed in favour of aquatic exercise. Although a statistically significant difference was not reached ( $p = 0.06$ ), the 95% CI indicates that aquatic exercise is likely to be as good or better than land-based exercise for



**Figure 8.** Weighted mean difference (95% CI) in the effect of aquatic exercise versus land-based exercise on the 39-item Parkinson's Disease Questionnaire test at the end of the intervention period.

<sup>a</sup> The data from the study by Shahmohammadi et al<sup>48</sup> are omitted due to heterogeneity – see main text and eAddenda for details.



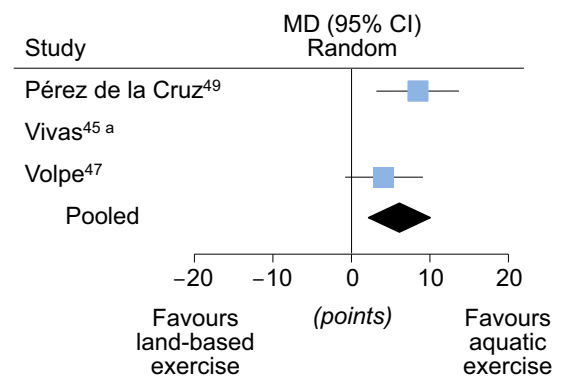
**Figure 9.** Weighted mean difference (95% CI) in the effect of aquatic exercise versus land-based exercise on components of the Unified Parkinson's Disease Rating Scale at follow-up.

this outcome. However, the small size of the pooled sample and the relative low quality of evidence on the GRADE assessment warrant cautious interpretation and the need for further studies to refine the estimate of the relative effects of the two types of exercise on this outcome.

High-quality evidence was detected in quality of life outcomes assessed by PDQ-39, supporting the valuable effect of aquatic exercise in improving the health-related quality of life of people with PD.<sup>46,47,50</sup> The results of this meta-analysis revealed a significant between-group difference in favour of aquatic exercise, with an average decrease (ie, improvement) of 6.0 points (95% CI -11.3 to -0.6) in the PDQ-39 in favour of the aquatic exercise group.

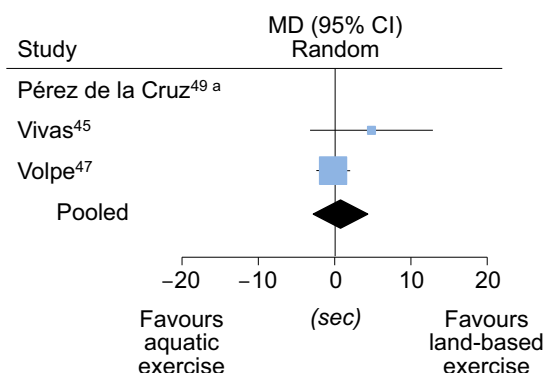
The significant between-group difference in the BBS score observed at the end of treatment in favour of the aquatic exercise training was maintained at the follow-up assessment (MD 6.3, 95% CI 2.1 to 10.5). This suggests that the greater benefit of aquatic exercise than land-based exercise on balance capacity is likely to persist over time.<sup>53</sup>

It is certainly important to consider whether the statistically significantly greater effects of aquatic exercise over land-based exercise on BBS, Falls Efficacy Scale and quality of life are clinically important. Ideally, this should be judged by whether the extra benefit outweighs any extra cost, risk, effort and inconvenience involved in undertaking aquatic exercise instead of land-based exercise. Although



**Figure 11.** Weighted mean difference (95% CI) in the effect of aquatic exercise versus land-based exercise on the Berg Balance Scale at follow-up.

<sup>a</sup> The data from the study by Vivas et al<sup>45</sup> are omitted due to heterogeneity – see main text and eAddenda for details.



**Figure 12.** Weighted mean difference (95% CI) in the effect of aquatic exercise versus land-based exercise on the Timed Up and Go test at follow-up.

<sup>a</sup> The data from the study by Pérez de la Cruz et al<sup>49</sup> are omitted due to heterogeneity – see main text and eAddenda for details.

such thresholds have not been determined, the low ends of CIs (ie, 1.6 on the BBS, 1.8 on the Falls Efficacy Scale and 0.6 on the PDQ-39) would all not exceed even a very low threshold. Therefore, regardless of the threshold chosen, it is not possible to state with certainty that aquatic exercise should be actively recommend over land-based exercise to obtain greater benefits that patients would typically say outweigh any extra drawbacks of the aquatic format. However, if patients are equally happy to do aquatic exercise or land-based exercise, or if they only have access to aquatic exercise, then they can be assured that it is very unlikely that they will have any less benefit from the aquatic format and they are likely to get some small to moderate extra benefits.

In line with these considerations, some of the strengths of this review, particularly in comparison with previous reviews on this topic, are that it appraised evidence from randomised trials only, and also gathered information on the safety, feasibility, pool depth, water temperature and the amount of supervision provided by the aquatic physiotherapists. Overall, the included trials indicated that aquatic exercise is a safe and feasible approach for people with PD, with only two out of 187 participants dropping out of the study due to adverse events reported following aquatic exercise training (orthostatic hypotension or respiratory problems).<sup>47</sup> Moreover, supervision by a physiotherapist was well documented in all the included studies. Pool depth and water temperature need to be taken into account in PD rehabilitation to ensure the safety of the intervention that is administered.<sup>20</sup> For instance, water temperature is of importance because people with PD are at greater risk of orthostatic hypotension,<sup>54</sup> which can affect their capacity to exercise safely in water.<sup>20</sup> The pool depth is also a factor that needs to be controlled because the increased hydrostatic pressure with deeper water<sup>20</sup> may result in some patients experiencing respiratory problems.<sup>55</sup>

Despite a comprehensive search strategy, the present study highlights that further data on aquatic exercise in people with PD are still needed, with six studies eligible for meta-analysis. Other limitations of this review were: a limited number of participants; heterogeneity of training programs and follow-up characteristics; testing at different therapy phases (On/Off); and the absence of agreement on a core set of outcomes.

These findings are consistent with the observation that evaluation of non-motor impairments is frequently lacking in clinical practice and intervention trials,<sup>56</sup> with only one study investigating pain severity using the visual analogue scale for pain assessment.<sup>49</sup> Even if PD is typically classified as a movement disorder, non-motor impairments such as depression, pain, apathy, fatigue and cognitive

**Table 4**  
Grades of Recommendation, Assessment, Development and Evaluation (GRADE) quality of evidence.

Outcome	Design	Risk of bias	Indirectness	Inconsistency	Imprecision	Publication bias	Effect size	GRADE quality
UPDRS Total score at end of treatment <i>I</i> <sup>2</sup> = 0%, MD -0.1, 95% CI -7.7 to 7.5	2 RCTs	-2 <sup>a</sup>	0	0	-2 <sup>b</sup>	0	0	Very low
UPDRS-II at end of treatment <i>I</i> <sup>2</sup> = 0%, MD 0.7, 95% CI -1.2 to 2.5	2 RCTs	-1 <sup>c</sup>	0	0	-2 <sup>b</sup>	0	0	Very low
UPDRS-III at end of treatment <i>I</i> <sup>2</sup> = 0%, MD -1.1, 95% CI -2.2 to 0.0	4 RCTs	-1 <sup>c</sup>	0	0	-1 <sup>d</sup>	0	0	Low
BBS at end of treatment <i>I</i> <sup>2</sup> = 0%, MD 2.7, 95% CI 1.6 to 3.9	5 RCTs	-1 <sup>c</sup>	0	0	0	0	0	Moderate
TUG at end of treatment <i>I</i> <sup>2</sup> = 41%, MD -0.8, 95% CI -2.2 to 0.5	4 RCTs	-1 <sup>c</sup>	0	0	-2 <sup>b</sup>	0	0	Very low
ABS at end of treatment <i>I</i> <sup>2</sup> = 71%, MD 6.5, 95% CI -8.9 to 21.6	2 RCTs	-1 <sup>c</sup>	0	-1 <sup>e</sup>	-2 <sup>b</sup>	0	0	Very low
FES at end of treatment <i>I</i> <sup>2</sup> = 0%, MD -4.0, 95% CI -6.1 to -1.8	2 RCTs	-1 <sup>c</sup>	0	0	-1 <sup>d</sup>	0	0	Low
QOL outcomes (PDQ-39) at end of treatment <i>I</i> <sup>2</sup> = 38%, MD -6.0, 95% CI -11.3 to -0.6	3 RCTs	0	0	0	0	0	0	High
UPDRS Total score at follow-up <i>I</i> <sup>2</sup> = 54%, MD 0.5, 95% CI -9.1 to 10.0	2 RCTs	-2 <sup>a</sup>	0	-1 <sup>e</sup>	-2 <sup>b</sup>	0	0	Very low
UPDRS-III at follow-up <i>I</i> <sup>2</sup> = 0%, MD 0.8, 95% CI -3.5 to 5.1	2 RCTs	-1 <sup>c</sup>	0	0	-2 <sup>b</sup>	0	0	Very low
BBS at follow-up <i>I</i> <sup>2</sup> = 30%, MD 6.3, 95% CI 2.1 to 10.5	2 RCTs	-1 <sup>c</sup>	0	0	-1 <sup>d</sup>	0	0	Low
TUG at follow-up <i>I</i> <sup>2</sup> = 28%, MD 0.9, 95% CI -2.8 to 4.6	2 RCTs	-1 <sup>c</sup>	0	0	-2 <sup>b</sup>	0	0	Very low

Risk of bias was estimated using the Physiotherapy Evidence Database (PEDro) Scale.

ABC = Activities-specific Balance Confidence, BBS = Berg Balance Scale, FES = Falls Efficacy Scale, *I*<sup>2</sup> = inconsistency statistic, MD = weighted mean difference, PDQ-39 = 39-item Parkinson's Disease Questionnaire, PEDro = Physiotherapy Evidence Database scale, QOL = quality of life, RCT = randomised controlled trial, SMD = standardised mean difference, TUG = Timed Up and Go test, UPDRS = Unified Parkinson's Disease Rating Scale.

<sup>a</sup> Downgraded two places as most of the trials scored ≤ 4 on the PEDro scale.

<sup>b</sup> Downgraded two places due to very large confidence interval and imprecision.

<sup>c</sup> Downgraded one place as most of the trials scored ≤ 6 on the PEDro scale.

<sup>d</sup> Downgraded one place due to large confidence interval.

<sup>e</sup> Downgraded one place due to an inconsistency statistic (*I*<sup>2</sup> ≥ 50%).



disorders are common complications. In people with PD, these play a key role in determining global disability, often affecting quality of life more than the motor disturbances.<sup>57–59</sup>

Properly planned and adequately powered randomised trials with a comprehensive set of shared outcomes are warranted to clarify the effects of aquatic exercise in people with PD. Future studies should seek agreement on the use of homogeneous degrees of disease severity, a standardised medication phase during the assessments (On/Off), comparable drug types and doses, specific PD-related clinical outcomes and uniform exercise dosages (ie, intensity, frequency, duration and standardised follow-up period) with fixed exercise alternatives (eg, land-based exercise).

In conclusion, the present systematic review showed that aquatic exercise seems to improve the motor impairments of PD significantly more than no intervention, and has greater benefits than land-based exercise on balance capacity, fear of falling and health-related quality of life, with similar effects as land-based exercise on other outcomes in PD populations with a mild to moderate degree of disability. Therefore, if patients prefer the aquatic setting and have the possibility to carry out a rehabilitation protocol in hydrotherapy pools, then they can accept it knowing that it is not inferior to land-based exercise. Furthermore, because some of the outcomes analysed in this review revealed better results following an aquatic exercise program, clinicians or patients who have the chance to choose among different rehabilitation protocols may opt for aquatic exercise rather than land-based exercise, especially in presence of relevant motor impairments (ie, shuffling gait, start hesitation, freezing of gait, festination, impaired gait propulsion and difficulty in turning), which may increase the risk of falling during exercise. However, the potential extra costs and complexity of aquatic context need to be considered case by case in this clinical decision.

**What was already known on this topic:** Various forms of land-based exercise have been shown to be beneficial for people with Parkinson's disease. Water-based exercise has also become very popular in the management of disease severity and motor impairments in people with Parkinson's disease, but the evidence for it has not been adequately summarised.

**What this study adds:** The existing limited evidence seems to suggest that aquatic-based exercise may improve motor impairments in people with Parkinson's disease significantly more than no intervention. Overall, aquatic-based exercise has effects that are at least as good as those of land-based exercise. The additional benefits of aquatic exercise over land-based exercise may occur with balance capacity, fear of falling and health-related quality of life, although the magnitude of each extra benefit may be small.

**eAddenda:** Figures 3 and 10, Table 3 and Appendices 1 and 2 can be found online at <https://doi.org/10.1016/j.jphys.2019.02.003>.

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