Aquatic Exercise Therapy for People with Parkinson’s disease: a Randomized Controlled Trial
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Title: Aquatic Exercise Therapy for People with Parkinson’s disease: a Randomized Controlled Trial

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This manuscript entitled “Aquatic Exercise Therapy for Parkinson’s disease: A Randomized Controlled Trial” has not been published previously. All authors declare that they have contributed to this paper, have no conflict of interest and have approved the final manuscript.

Acknowledgments
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The author gratefully acknowledges the help and support of Margaret Richardson,
Parkinson’s Disease Nurse Specialist, Dr. Valerie Power, Post-Doctoral Researcher,
University of Limerick and Andrew Ward, Codamotion, UK.

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Abstract

Objective: To evaluate the effects of aquatic exercise therapy on gait variability and disability compared to usual care for people with Parkinson’s disease (PD).

Design: Single-blind randomized control trial (RCT).

Setting: A community based hydrotherapy pool in Ireland.

Participants: Twenty one individuals with PD (Hoehn-Yahr Stages I-III).

Interventions: Participants were randomly assigned to either an aquatic exercise therapy group (45 minutes, twice a week for 6 weeks) or a control group that received usual care.

Main Outcome Measure(s): The primary outcome measure was gait variability as measured using a Coda CX1 motion capture system. Secondary outcomes were quality of life measured on the Parkinson’s Disease Questionnaire-39, freezing of gait and motor disability quantified by the Unified Parkinson Disease Rating Scale (UPDRS III). Feasibility was evaluated by measuring safety, adverse events and participant satisfaction.

Results: People in the aquatic therapy group and control group showed similar small improvements in gait variability. The aquatic therapy group showed greater improvements in disability than the control group ($P<0.01$). No differences between groups or over time were identified for freezing of gait or quality of life. Aquatic therapy sessions were safe and enjoyable with no adverse events.

Conclusions: Aquatic therapy appears feasible and safe for some people in the early stages of Parkinson’s disease.

Keywords: Aquatic therapy; Parkinson’s disease; gait; rehabilitation; exercise; physiotherapy.
Aquatic exercise therapy for people with Parkinson’s disease (PD) has become a recent focus of attention, given emerging evidence that physical activity has the potential to be both enjoyable and have neuroprotective effects. \(^1\) Parkinson’s disease is associated with impairments of movement, especially a reduction in step length and gait speed. \(^3\) Freezing of gait (FOG) also occurs in up to half of individuals with PD. \(^5\) These gait disorders are associated with increased falls risk with more than 60% of people with PD experiencing a fall every year. \(^7\) Falls are associated with negative physical and psychological consequences including physical injuries, loss of independence, fear of falling and sometimes the need for residential care. \(^9\)

Exercise, physical activity and physiotherapy are core elements of a comprehensive rehabilitation program, alongside medical management of PD. \(^7\) People with PD are encouraged to maintain adequate levels of physical activity throughout the course of the disease and to try different forms of exercise over time, to maintain long-term exercise participation. \(^12\) Aquatic therapy is one form of exercise for people with early PD, alongside strategy training, \(^14\) progressive resistance strength training, \(^7\) cycling, \(^15\) tai chi, \(^16\) therapeutic dancing \(^17,18\) and walking programs. \(^19,20\) Aquatic therapy enables some people with PD to move more easily while reducing the fear of falling. \(^21,22\) Aquatic therapy can also improve balance and functional mobility in some individuals with PD. \(^22–24\) The current evidence to support the use of aquatic therapy to improve gait in adults with neurological conditions including PD is mainly derived from small pilot trials. \(^25,26\) The mixed outcomes of previous studies appear related to the variability in intensity and dose of the aquatic therapy, sample characteristics and the outcome measures used to assess change.
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The assessment of gait variability is recommended as research has shown a strong link between increased variability of gait and falls risk in people with PD. Gait variability is a loss of consistency in the production of a steady, rhythmic gait. Measuring variability using three-dimensional gait analysis enables sensitive and reliable quantification of changes in gait performance over time.

The primary aim of this study was to evaluate the effects of a six-week aquatic therapy program compared to usual care on gait variability, motor disability, freezing and health related quality of life in people with mild-moderately severe PD. We hypothesized that, compared to a group that received usual care, the aquatic exercise therapy group would show reduced variability in step length, improved motor disability, less freezing and improved quality of life. We also predicted that aquatic therapy would be viable and safe for people with PD.

**Method**

**Participants**
A sample of convenience of 21 participants (14 men, 7 women; mean age ± SD, 71.42 ± 4.9 years) with idiopathic PD, who were deemed eligible to partake in the study by their chartered physiotherapist or specialist PD nurse were recruited. Volunteers received an information leaflet about the study and were asked to provide written informed consent prior to participating in the study. Recruitment took place from March to May 2015. All volunteers lived in the Munster region of Ireland. Ethics approval was received from the Irish Health Service Executive, Hospital Scientific Research Ethics Committee (ethics number 014/15).
Inclusion criteria were a diagnosis of idiopathic PD according to the UK Brain Bank Criteria\(^\text{31}\) confirmed by a neurologist; Hoehn and Yahr stage I-III; stable medication status over the past three months.\(^\text{32}\) Participants were required to be able to walk 10 meters three times, without assistance.\(^\text{14}\) They were excluded if they had contraindications to aquatic therapy including cardiovascular or pulmonary conditions,\(^\text{22}\) previous history of deep brain stimulation\(^\text{7}\) or any musculoskeletal condition that affected their ability to participate in the exercise group.\(^\text{26}\)

Twenty-one participants were randomized and allocated into two groups: the physiotherapy treatment group (n=11) who had aquatic therapy and usual care, and the control group (n=10) who continued with their usual care involving medication alone (table 1). Randomization was carried out using sequentially numbered sealed envelopes and this procedure was conducted by a third party. Opaque envelopes were used to conceal allocation. All participants were blinded to group allocation.

**Assessments**

Assessments took place one week before the six-week aquatic or control intervention (T1) and one week after intervention completion (T2). All assessments were carried out by a trained physiotherapist (LC). To minimise performance variability due to the effects of medication, participants were assessed at the same time of the day, 1 and 2.5 hours after their last medication dose (‘on’ medication phase).\(^\text{33}\) Participants in both groups were instructed to continue with their usual care and advised not to change their typical exercise routine. Each participant was asked to inform the
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physiotherapist running the group of any changes to their medication or exercise habits throughout the six weeks of the trial.

Outcome Measures

A dual CODA CX1® motion capture system (Charnwood Dynamic Ltd., Leceistershire, UK) was used to analyse three-dimensional (3-D) gait and measure the primary outcome measure. This 3-D system uses optical sensors fixed onto parallel rigid frames to detect infrared light signals which were consecutively pulsed at a sampling rate of 200 Hz from the markers positioned at anatomical landmarks on the lower body. In accordance with previous research 20 active LED markers were positioned on the pelvis and lower body segments bilaterally. The spatiotemporal gait variables measured were step length (distance between two consecutive footprints), step time (timing of the gait cycle for each step) and step width (distance between the medio-lateral ankle joint centers). Terminal swing end (TSE), initial contact (IC) and toe off (TO), were selected manually within Odin softwear (version 1.01.xx) using standardised definitions for the gait events. Data were exported to SPSS© version 22 for further analaysis.

Procedure

Following a gait familiarisation trial, participants were instructed to walk at their “comfortable walking pace”, for a minimum of 10 trials on a 10 meter walkway. They were instructed to take rest breaks as required between each trial. Steps recorded during each test were combined across trials with a minimum of 60 steps (30 steps on the left and 30 steps on the right). Fifty or more steps is suggested as optimal when calculating gait variability, with 10 or more gait trials recommended.
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standard deviations for left and right steps were calculated separately and then combined to determine gait variability. The combined standard deviation was determined by calculating the square root of the mean variance of the left and right steps.

For the secondary outcome measures, health-related quality of life was quantified by the Parkinson’s Disease Questionnaire-39 (PDQ-39). Severity of PD was categorised using the Unified Parkinson’s Disease Rating Scale (UPDRS) motor subsection III. Freezing was assessed using a six point FOG questionnaire. These tools have been found to be both valid and reliable measures and were used in previous studies investigating the effects of aquatic therapy on people with PD.

Demographic details such as age, disease duration, weight and height were also recorded for each participant.

The feasibility of implementing the aquatic therapy intervention was also assessed by recording adverse events such as falls, extreme fatigue or changes in PD symptoms throughout the six-week intervention phase. We also quantified levels of recruitment, attendance and attrition rates. An exit questionnaire captured the experiences and viewpoints of participants. The questionnaire incorporated a five point Likert scale to examine changes in health and wellbeing in the participants following aquatic therapy intervention.

**Intervention**

Participants in the intervention group attended aquatic therapy (two 45 minute sessions each week for six weeks) in a local hydrotherapy pool which was 12 meters
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long and six meters wide with a graded depth, varying from 0.6 meters to 1.30 meters.

The water temperature was set at 32°C and air temperature set at 31°C. A trained lifeguard was present on the pool deck at all times. Aquatic therapy was delivered by a physiotherapist with eight years post-graduate experience in aquatic therapy.

Aquatic therapy intervention occurred during the period from May to October 2015.

Defining the optimal intensity for aquatic gait training was determined from first principles as there was no standard measure for evaluating intensity of gait training in water for people with PD. Each session comprised a cardiovascular and stretching warm-up for 10 minutes, followed by 25 minutes of specific gait training exercises based on recommendations from guidelines recently published in the European Physiotherapy Guideline for Parkinson’s disease and a 10 minute cool down (Appendix A). Many of the water-based exercises followed a water specific therapy (WST) approach as outlined in Lambeck and Gamper. Exercises were progressed according to individual ability by increasing the numbers of repetitions, the period of aerobic training, the amount of resistance, the level of difficulty of a task (such as walking with or without fins). A written recording of each class was completed by the physiotherapist to document each participant’s self-reported performance and the Borg Rating of Perceived Exertion (RPE) scale was scored during each session.

Participants were monitored using a 1-10 Borg RPE scale, which was used as a means of increasing both the intensity and challenge of the therapeutic protocol. When ratings were reported below four (moderate difficulty), a progression was introduced following the format outlined in Appendix A.

Statistical Analysis
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Sample size calculations were based on motor disability effect sizes from previous studies of people with PD. An a-prior sample size calculation, based on UPDRS III scores with a 10% drop out rate, 80% power and alpha set at 0.05 showed that we needed at least 10 participants in each group.

Preliminary descriptive analyses were generated for all variables to present the demographic and clinical characteristics of the groups. We checked to ensure that no differences between groups existed for baseline characteristics using independent t-tests and chi-square analyses. The majority of variables were not normally distributed hence Mann-Whitney U-tests were used to determine differences in variables for between–subject factors (aquatic therapy versus control) and Wilcoxon signed rank tests for within-subject factors (time1 versus time 2). Descriptive statistics included the median (Md) and Inter-Quartile Range (IQR) with a P value of <0.05 considered to be statistically significant. The Statistical Package for Social Sciences (SPSS©) version 22 (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses.

Results
Of the 21 participants, 11 were randomized into the intervention group with all completing the aquatic therapy program. Data from one participant was excluded from the final analysis as they received medical intervention for a flare up of fibromyalgia symptoms not related to PD just before testing. Ten participants were randomized into the control group with the data from two participants excluded prior to follow up due to an episode of acute back pain and transportation difficulties (Figure 1). Intention to treat analysis using last observation carried forward (LOCF) was carried out, including for the UPDRS III.
There were no statistically significant differences between groups at baseline including for age, disease duration and levodopa equivalent dose (LED) (Table 1.) The pre-post test results are provided in Table 2. There were no significant differences observed between groups for changes in gait variability over the course of therapy (Table 2). Nevertheless, after aquatic therapy, variability was reduced for step length (Mdn @T1 = 0.03; Mdn @ T2 = 0.02) and step time (Mdn @T1 = 0.02; Mdn @T2 = 0.01). There were no changes in gait variability in the control group over the course of the study.

A key finding was a statistically significant improvement in motor disability in the aquatic therapy group as shown by improvements in the UPDRS III ($P=0.01$). The effect size was 4.5 between the medians (13-17.5). Given the report by Shulman et al. this difference in median scores would denote a moderate clinically important difference for the UPDRS motor score. There was no difference between groups for the quality of life or freezing of gait questionnaires, with small improvements in scores observed for both questionnaires in the intervention group only.

Feasibility

The aquatic therapy was found to be feasible and safe, with no adverse events, extreme fatigue or exacerbation of PD symptoms reported. There was no attrition in the intervention group although two participants attended 11 of the 12 sessions due to medical appointments. There was a 100% attendance recorded for the other participants.
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The results from the exit questionnaire showed the aquatic exercise program to be very enjoyable with 90% expressing a strong interest in continuing the classes (Figure 2). Overall, 70% of participants reported improvements in their walking and confirmed that the programme was challenging. Participants enjoyed being “challenged” and felt that “progression was evident in the skills thought”. The majority of participants reported that walking with the “flippers (fins) was probably the most difficult but still beneficial”. Most described the exercises stepping up exercises as the most beneficial exercise as it “brought about a sense of achievement and confidence in my walking”. When asked which exercises included in the programme were least beneficial, most reported that “all exercises had a purpose” and were “beneficial.”

Discussion
This randomised trial showed that aquatic therapy was associated with improvements in motor function as measured by the UPDRS III. Aquatic therapy was also feasible and safe in this sample of people with mild to moderately severe PD, with no adverse events reported. These findings are in agreement with the preliminary international trials by Vivas et al 23 and Ayán and Cancela. 32

Contrary to predictions, no significant group differences were found for the gait variability in relation to step length, step width or step time. The negligible changes in gait variability might have been related to the relatively short intervention period. A six week intervention period was chosen based on local usual clinical practice, a previous research study in Spain 23 and clinical guideline recommendations. 11 Whilst Vivas et al 23 found improvements in postural stability following four weeks of
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aquatic therapy (45 minutes twice weekly), other studies reporting changes following aquatic therapy had interventions between two to five months. 22,25,26,32

Aquatic therapy was challenging and enjoyable for the participants with PD in this study. Biomechanically, walking in water may be easier for people with PD due to an increased resistance to movement from the drag forces of water along with a reduction in actual body weight as a result of buoyancy forces. 24 While the protocol used in this program may be adapted for larger controlled trials, further studies examining intensity, dose effects and long-term benefits for aquatic therapy in PD are warranted. Efforts were made to monitor intensity throughout each class however the endurance and fitness levels of the participants were varied at baseline as indicated by the Borg RPE scale, which resulted in participants progressing at different rates.

Recruitment of participants was challenging. Over half of the eligible participants declined, with an acceptance rate of 48%. Reasons given for not participating included an inability to swim, with few reporting a fear of water. This varies from other PD aquatic studies 22,32 and may reflect sample characteristics. To increase sample sizes, future studies should consider providing the aquatic therapy intervention across several centres; as well as offering water confidence sessions, possible adopting a Halliwick approach, 49 prior to the commencing the trial.

Study Limitations

There were some limitations of this trial. Firstly, the small sample size may have impacted on the ability to detect significant changes in gait variability. The sample size calculation was based on an estimate of the changes reported for the UPDRS as at
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the time there were no other published studies which directly assessed the effects of aquatic therapy on gait variability. The current study has a small sample size, and generates new data that can be used for accurate sample size calculation for future studies, including for gait variability. Secondly, although testing occurred at the same time of the day, we could not rule out the bias introduced by fluctuations in levodopa plasma concentrations. Nevertheless, there were no changes to anti-Parkinson’s medication reported between T1 and T2 in each group. While all patients were tested and treated during the ‘on’ medication phase, the effect of aquatic therapy during the ‘off’ state needs to be established. This trial tested people with early to middle stage PD and the effects of aquatic therapy on people who are in the more advanced stages remains unknown.

Conclusion
In this small feasibility trial, group aquatic therapy delivered over a six week period did not improve gait variability to a greater extent than usual care. Aquatic exercise therapy was associated with improvements in motor disability and was safe, enjoyable and feasible in the early stages of PD. Prospective large scale randomized long-term studies are needed to establish whether group aquatic therapy can have a positive influence on gait and wellbeing in people with progressive neurological conditions.

List of abbreviations
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IQR: Interquartile Range. LOCF: last observation carried forward. LED: levodopa equivalent dose.

References


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Suppliers

a) CODA CX1® motion capture system, Charnwood Dynamic Ltd., Victoria Mills, Rothley, LE7 7PJ, UK.

b) SPSS© Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL, 606060.

Figure Legends

Figure 1. Flow diagram of study procedures

Figure 2. Aquatic group participant feedback

Questions scored using 5-point Likert scale (1 = strongly agree, 2 = somewhat agree, 3 = neither agree nor disagree, 4 = somewhat disagree, 5 = strongly agree)