RESEARCH ARTICLE

# Effects of aquatic and dry land physiotherapy on the functional capacity in individuals with and without parkinson's disease: a protocol study followed by a randomized clinical trial [version 1; peer review: awaiting peer review]

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## Abstract

### Background

Individuals with Parkinson's Disease (PD), particularly those with the rigid-akinetic with postural instability (RA) subtype, often experience motor symptoms that impair functionality and postural control. Physiotherapy interventions, including both dry land and aquatic therapies, can help manage PD treatment. This study aimed to develop and assess the effects of two exercise protocols emphasizing the extensor musculature of the vertebral column (dry land and shallow water) on functional capacity in individuals with and without RA-type PD.

### Methods

The study utilized a protocol study followed by a randomized clinical trial, with the registry number NCT04863118, involving ten RA-type PD

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**Approval Status** *AWAITING PEER REVIEW*

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(intervention group) and ten individuals without PD (reference group). Participants underwent exercise protocols of varying intensity levels, and their pre and post-intervention functional capacity were evaluated using standardized tests. The applicability and safety of these protocols were assessed through a self-perception questionnaire.

**Results**

Significant improvements were observed in functional capacity parameters following both dry land and aquatic physiotherapy interventions among PD individuals, including increased repetitions in the Sit-to-Stand test and reduced completion time in the Timed Up and Go test. Similar positive outcomes were observed in individuals without PD, indicating the efficacy of these interventions irrespective of PD status.

**Conclusion**

A single session of physiotherapy, whether on dry land or in shallow water, focusing on the extensor musculature of the vertebral column, enhances functional capacity in PD and non-PD individuals alike. Furthermore, the protocols demonstrated safety, comfort, and acceptability, promoting treatment adherence and future recommendations. These findings support the implementation of these protocols in clinical practice, aiding therapists in enhancing rehabilitation outcomes while ensuring individual safety.

**Registration**

Name of registry: Acute Effects of Strength Training and High Intensity Training on Functional and Biochemical Measurements of Individuals With Parkinson's Disease in Different Environments and Depths

Registry number: NCT04863118

Registration date:, 09/02/2024

URL: https://clinicaltrials.gov/study/NCT04863118.

**Keywords**
Parkinson's Disease, physiotherapy, hydrotherapy, functional capacity, exercise

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## Introduction

Parkinson's Disease (PD) is the second most prevalent neurodegenerative disease worldwide,[1] characterized by progressive loss of dopaminergic neurons in the substantia nigra, leading to a significant decrease in dopamine levels and subsequent impairment of functional capacity and balance.[2] Within the general diagnosis of PD, some authors suggest two subtypes related to predominant motor characteristics: tremor dominant (TD) and rigid-akinetic type with postural instability (RA),[3] presenting different clinical courses and prognoses,[4,5] which should be considered in clinical practice. Individuals with RA-type PD have a greater reduction in dopamine levels compared to TD-type, resulting in a faster and more debilitating disease progression.[4]

Individuals with RA-type PD present increased muscle tone and decreased range of motion, leading to impairment in postural adjustments and compromised execution of activities of daily living.[6,7] Among the main motor alterations observed in individuals with PD, attention is drawn to the reduction in strength of the extensor musculature compared to the flexor musculature of the vertebral column - one of the causes of flexed posture, resulting in postural instability and balance deficits, as the center of mass is displaced anteriorly, placing the individual at the limits of stability.[8,9] Additionally, individuals with PD experience a reduction in force production capacity and increased fatigue of the extensor musculature of the vertebral column compared to individuals without PD.[9] This picture of postural instability associated with the reduced force generation capacity of the extensor musculature in individuals with PD reinforces the need for a well-described exercise protocol with emphasis on this muscle group in this population.

Some non-pharmacological therapies can be used in the treatment of PD to improve the signs and symptoms of the disease. Within physiotherapy, two modalities widely used in clinical practice are dry land physiotherapy (DL) and aquatic physiotherapy (AP).[10] The literature provides evidence that balance exercises on dry land and in water can improve motor symptoms, mobility, balance, and therefore the quality of life of people with PD.[11,12] The use of different environments provides even more neurosensory motor stimuli that are important for motor skills.[13,14] Thus, it can be understood that practicing exercises in both environments can be additional and beneficial for people with PD. Furthermore, different types of physiotherapeutic interventions - such as strength exercises, high-intensity training, progressive resistance, aerobic exercises, and walking and balance training - have positive clinical effects on parameters of functional capacity and balance in individuals with PD. However, studies often do not stratify the different subtypes of PD and do not report the exercise protocols applied in detail.[15–17]

Despite the existing evidence regarding the relationship between physiotherapy and potential benefits in PD, there are limitations regarding articles that present well-described exercise programs, documenting the intensity and levels of exercise progression, especially concerning aquatic therapy, as there is a scarcity of studies in the área.[18] Furthermore, there is a gap in the literature regarding research addressing specific exercise protocols for the extensor musculature of the vertebral column, which is crucial for the RA subtype of PD, commonly affected by postural instability. Therefore, it is necessary to establish a specific exercise protocol with emphasis on the extensor musculature of the vertebral column, trunk stabilizers, in order to alleviate the degeneration process in individuals who have not yet presented such alterations and for the maintenance of existing ones. Some authors note that aspects such as mobility and postural instability, as well as balance disturbances, do not respond well to medication or surgery, therefore prevention is considered an important alternative.[19] Thus, this present work consists of a protocol study followed by a subsequent randomized clinical trial with the application of a single session. The protocol study comprises two exercise protocols emphasizing the extensor musculature of the vertebral column, one on dry land and the other in the aquatic environment, developed by the researchers. Subsequently, a randomized clinical trial was conducted, which analyzed the effect of a single session to investigate the acute effects of physiotherapy on dry land and aquatic physiotherapy on functional capacity in the same population, as well as to verify the applicability and safety of the two protocols. Our hypothesis was that both training protocols with emphasis on the extensor musculature of the vertebral column would have positive effects on the functional capacity of individuals without PD and with rigid-akinetic type PD with good execution safety, without differences between them.

## Methods

### Trial design

This present study comprises a protocol study followed by a randomized clinical trial with the application of a single session.

The protocol study comprises two exercise protocols (on dry land and in the aquatic environment) with emphasis on the extensor musculature of the vertebral column in individuals without PD and with rigid-akinetic type PD. The exercise protocols on dry land and in shallow water are detailed in Table 1 and 2 (Underlying data),[43] respectively, and illustrated in Figures 1 for the dry land protocol and 2 for the shallow water protocol.

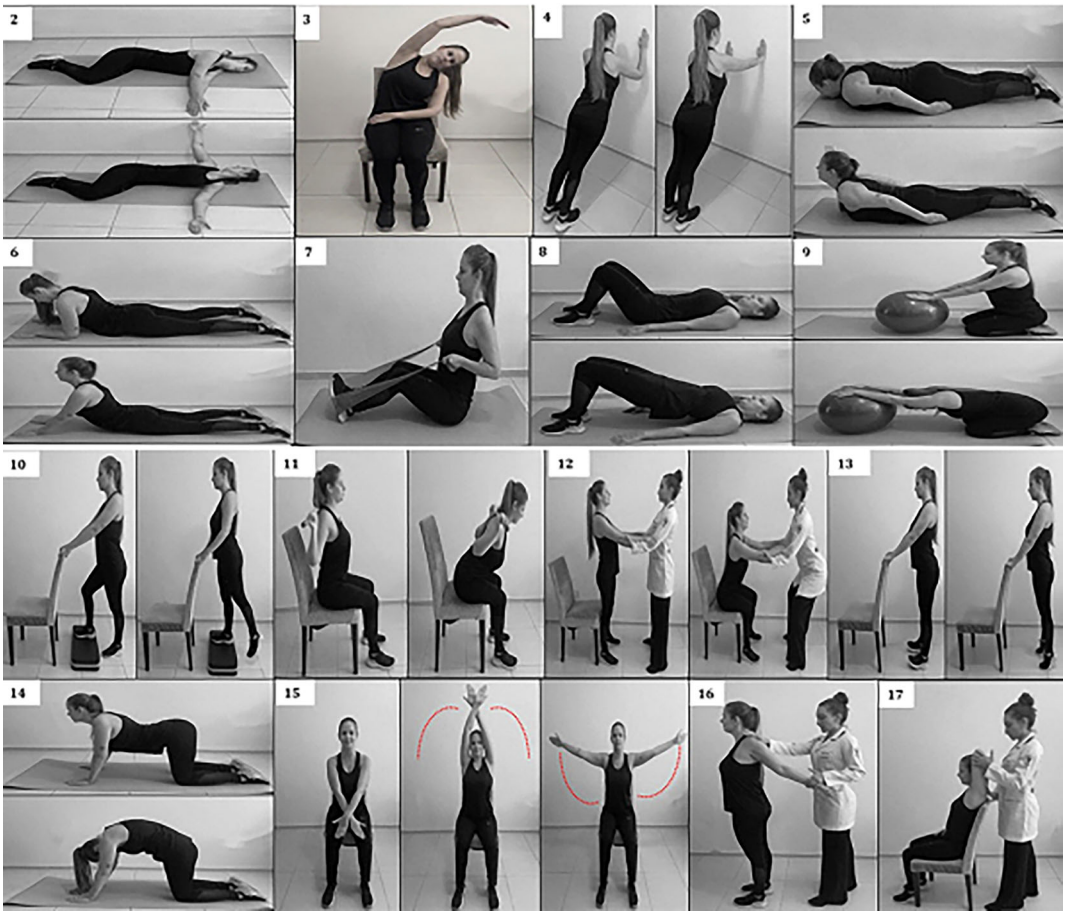


**Figure 1. Referring to the easy level of dry land exercises.**

Both protocols were developed by the researchers based on their experience in the field and with exercises demonstrated through images produced by themselves (Figures 1 and 2), with descriptions of execution and progression levels for each exercise.[20] The number of sets and repetitions for each exercise was standardized (Tables 1 and 2) (Underlying data).[43] The intensity of the exercises was monitored using the Borg Rating of Perceived Exertion Scale 6-20,[21] with the zones of interest being 15 (hard) to 18 (very hard). Thus, the intensity of the exercises respected the individual physical fitness level of each participant.

The exercise program on dry land (DL) began with a 10-minute warm-up. Subsequently, trunk rotation and flexion exercises were performed for spinal mobility, followed by ten exercises to strengthen the spinal extensor muscles. Finally, the training concluded with muscle flexibility exercises and stretching.

The exercise program in shallow water (SW) started with 3 water displacement exercises for warm-up and acclimatization of individuals in the aquatic environment - totaling 10 minutes. Subsequently, exercises to strengthen the spinal extensor muscles were performed. Finally, the protocol was concluded with deceleration exercises, reaching movements, and stretches.

In both the dry land exercise protocol and the shallow water exercise protocol, implements were used to assist in individualized progression for each study participant. For DL, resistance bands, dumbbells, balls, steps, sticks, and chairs were used; for SW, floaters, dumbbells, shallow water platforms, and fixed bars were used - in addition, hydrodynamic and hydrostatic properties also served as a form of exercise progression - with increasing speed in exercise execution, for example.

After the detailed elaboration of the protocols, the researchers of this study decided to apply them to test their feasibility in the target population. Therefore, a randomized single-session clinical trial was conducted to verify the applicability and

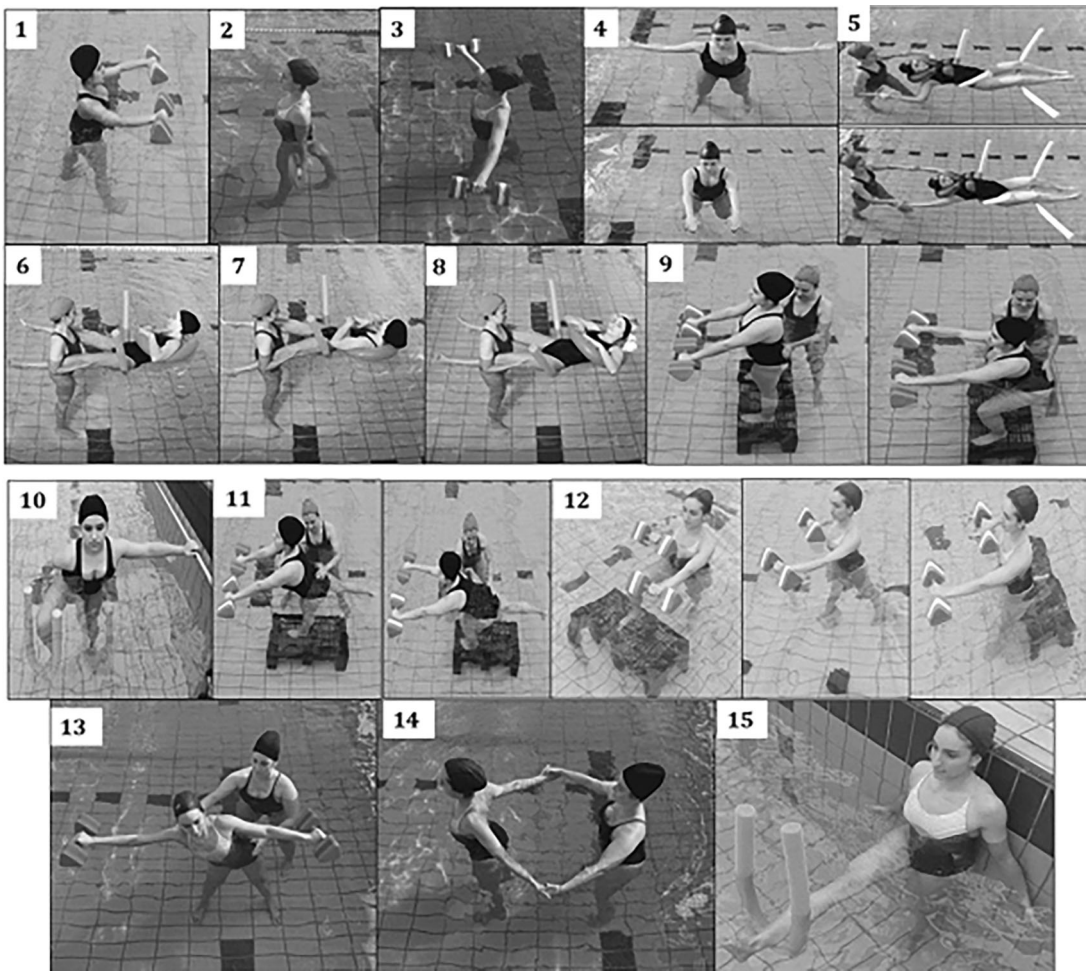


**Figure 2. Referring to the easy level of aquatic exercises.**

safety of the protocols and to investigate the acute effects of dry land physiotherapy and aquatic physiotherapy on the functional capacity and balance of individuals without PD and with RA-type PD. Functional measures of the participants were assessed both before and immediately after each exercise session. A 15-day washout period was observed between each modality.

The sample of this study consisted of an intervention group (IG) composed of individuals with PD with motor manifestation of the rigid-akinetic type and a reference group (RG) composed of individuals without PD.

The overall structure and flow of the study, from recruitment to intervention and assessment, are summarized in the study flowchart (Figure 3).

## Study setting

Participants in the IG were recruited through the Parkinson Association of Rio Grande do Sul (APARS) and through referrals from neurologists in the city of Porto Alegre, RS. Individuals in the CG were recruited from the Center of Aging and Movement (CREM) at the School of Physical Education, Physiotherapy, and Dance at the Federal University of Rio Grande do Sul (ESEFID-UFRGS). The recruitment and follow-up period it lasted from September 2022 to April 2023.

This study involved one researcher responsible for assessments and two researchers responsible for interventions (one for each group). Assessments were always conducted by the same researchers, as were the interventions, which took place on dry land and in shallow water. The dry land intervention was performed in a physiotherapy room, while the aquatic physiotherapy intervention was conducted in a heated pool with a depth of approximately 120 cm, With immersion at the level of the xiphoid process, individuals were distributed in the pool according to their height to avoid interference from

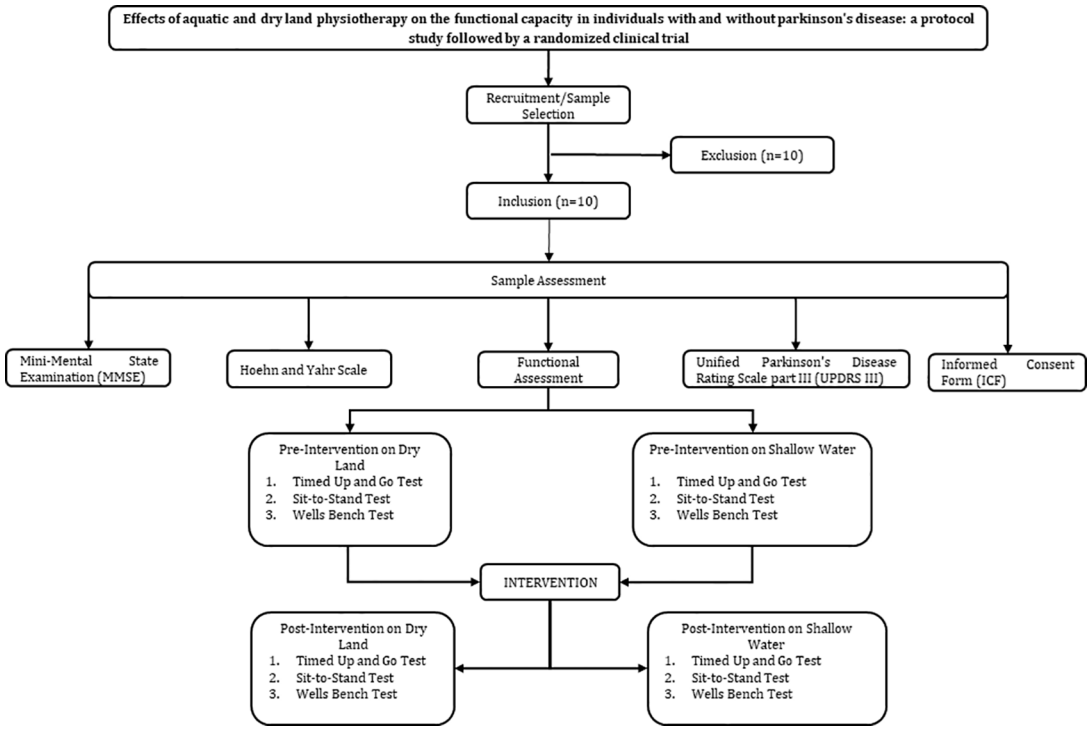


**Figure 3. Flowchart of the study protocol.**

depth during the performance of exercises in the aquatic physiotherapy session. All assessments and interventions were carried out on the premises of ESEFID-UFRGS.

## Eligibility criteria

The inclusion criteria for the IG were: age between 60 and 75 years old; diagnosis of PD for at least 6 months, of the RA type; classification on the Hoehn and Yahr scale from 1 to 3; preserved cognition assessed by the Mini-Mental State Examination (MMSE) with a cutoff score of 23/24; and all participants read and signed an informed consent form before being involved in the study. The inclusion criteria for the CG were: age between 60 and 75 years old; preserved cognition assessed by the MMSE with a cutoff score of 23/24; independent ambulation; and signing the ICF.

The exclusion criteria were: other associated osteomuscular and neurological pathologies; established dementia; pathologies and skin injuries that prevent entry into the aquatic environment; and hydrophobia.

## Interventions

The protocols on dry land and in shallow water are detailed in Tables 1 and 2 (Underlying data),[43] respectively, and illustrated in Figure 1 for the dry land protocol and Figure 2 for the shallow water protocol, as previously explained.

All sessions were conducted in small groups and under the direct supervision of the researchers to ensure proper technical execution of the exercises and minimize the risk of injury. Each intervention session lasted for 60 minutes.

## Outcomes

The main outcome of the study was the Timed Up and Go (TUG) test, with secondary outcomes including functional capacity (assessed by the Wells bench test, Sit-to-Stand test, Mobility and Well-being Self-perception Questionnaire), and the safety of the training protocols.

For individuals with PD, the Unified Parkinson's Disease Rating Scale part III (UPDRS III)[22] was used for sample characterization, and the Modified Hoehn and Yahr Scale[23] was used to assess functional disability in this population. Pre- and post-session balance assessment tests included the 30-second bipedal stance test with eyes open and closed, performed on a force platform,[24] repeated three times with a 2-minute interval. Our study considered times between 21 and 30 seconds for individuals to be classified as having no balance alteration, according to data proposed in the

literature by Matsudo, 2001.[25] The Berg Balance Scale (BBS)[26] was used for static and dynamic balance testing, where a BBS score of less than 45 indicates an increased risk of falls.[27]

The functional capacity assessment test was the Sit-to-Stand (STS) test, where participants were asked to stand up and sit down as quickly as possible without physical assistance for 30 seconds, timed without words of encouragement.[28] The Timed Up and Go (TUG) test[29] was also conducted to assess balance, mobility, risk of falls and functional capacity. It involves the time taken to stand up from a chair, walk around a cone, and return to sit down. Shorter times are associated with better balance and functional capacity.[30]

The flexibility test for the posterior muscles of the lower limbs was the Wells Bench test.[31] In this test, the participant flexes the trunk over the hip, pushing a wooden marker along a box with a millimeter-marked tape measure. This procedure is performed three times, considering the greatest distance reached.

Additionally, a questionnaire developed by the researchers was administered to assess self-perception of mobility and well-being before and immediately after. Two questions were formulated to inquire about how the subject was feeling at the moment (well-being, sensation of health, ability to perform daily activities), with responses ranging from 0 - no overall feeling of well-being and mobility to 10 - excellent overall feeling of well-being and mobility.

Finally, a questionnaire developed by the researchers after the intervention sought to evaluate the applicability and safety of the protocols conducted on dry land and in the aquatic environment. Eight questions were formulated to assess the feasibility, safety, self-perceived improvement in mobility, acceptance, and future use of the protocols, with scores ranging from 0 (low score) to 10 (optimal score).

## Assignment of interventions

*Allocation:* The order of conducting the exercise sessions on dry land and in water was randomized. The Randomizer program was used for randomization, forming blocks of 4 participants. Participants were scheduled at predetermined times; and participants with PD in the IG group performed the exercise protocols and assessments during the "ON" period of the anti-Parkinson's medication, to avoid interference from medication on the signs and symptoms of the disease.

**Blinding**: This study will employ a single-blind design, meaning that the individuals responsible for administering the assessment tools and conducting the laboratory analyses will be different from those implementing the intervention protocols.

## Statistical analysis

The sample size was calculated based on the TUG outcome data (Effect Size Calculated in G Power = 1.12)[32] in Oliveira et al. (2020),[33] mean/SD pre and post intervention, 12.79/1.83 and 11.03/3.49 respectively. Considering the significance level of 5% and statistical power of 85%, the final calculated sample size was of 10 participants per group.

The normality of the data was tested using the Shapiro-Wilk test. Results were presented as mean and standard deviation or median and interquartile range. Baseline and outcome measures were analyzed to check for differences between treatment modalities using paired sample t-tests, for normally distributed data, or Wilcoxon tests for non-normally distributed data. ANOVA or Kruskal-Wallis tests were used for comparing variables, with and without normality, respectively. The analysis was conducted using SPSS version 22.0 (IBM Corp., Armonk, NY) [https://www.ibm.com/spss]. An alternative open-source software option is JASP or R, which can also perform equivalent analyses.

The data were organized in an Excel spreadsheet and later analyzed using SPSS version 20.0. The Shapiro-Wilk test was used to assess data normality, revealing a non-parametric distribution. Continuous variables were expressed as medians (minimum-maximum), while categorical variables were represented by absolute and relative frequencies (n, %). Group frequency comparisons for categorical variables were conducted using the Mann-Whitney U test.

To evaluate changes in functional capacity before and after interventions, the Wilcoxon signed-rank test was employed for within-group comparisons, and the Mann-Whitney U test was applied to compare the differences (deltas) between dry land and aquatic physiotherapy interventions (between groups). A significance threshold of $p \leq 0.05$ was established, with effect sizes calculated using Cohen's "r" for significant outcomes ($r = z/\sqrt{n}$; 0.2-0.5: small effect, 0.5-0.8: moderate effect, 0.8 or higher: large effect).[34]

## Monitoring

*Data monitoring:* The formation of a Data Monitoring Committee has been deemed unnecessary due to the short duration of the study and the well-documented safety profile of aquatic physiotherapy for individuals with Parkinson's disease.

*Harms:* In this study, adverse events will be defined as any negative functional changes experienced by participants that are consistently associated with exercise intensity. These events will be documented after participants have provided informed consent and been enrolled in the study. Researchers will assess the relationship between the adverse event and the intensity of the exercise prescribed in the study, considering the timing and whether the event is unexpected or unexplained. If any situation arises that requires immediate medical attention, the emergency medical team within the Aquatic Physiotherapy department will be promptly contacted to ensure appropriate care.

*Auditing:* Given the single-center design of the study, the small sample size, and the well-established safety of the therapeutic intervention being used, external auditing is not considered necessary.

## Ethics and dissemination

*Ethics approval and consent*

This research was duly approved by the Research Ethics Committee of the Federal University of Health Sciences of Porto Alegre (CEP-UFCSPA) Research Ethics Committee under opinion number 4.546.442, on February 18, 2021 and registered on Clinical Trials under the title "Acute Effects of Strength Training and High Intensity Training on Functional and Biochemical Measurements of Individuals With Parkinson's Disease in Different Environments and Depths," with the registry number NCT04863118. The registration date is February 9, 2024, and further details can be accessed at https://clinicaltrials.gov/study/NCT04863118. This study adheres to the principles of Resolution 466/12 of the National Health Council and follows all ethical guidelines related to research involving human participants.[35]

The study was conducted at the School of Physical Education, Physiotherapy, and Dance of the Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, RS. All participants were invited to join the study voluntarily, and informed consent was obtained in writing from each participant. The Free and Informed Written Consent Form (ICF) was used in accordance with Resolution 466/12 of the National Health Council,[36] and all participants signed this form before enrolling in the study. No waiver of consent was requested or granted by the Ethics Committee.

*Protocol amendments*

While the prescribed protocol has been deemed safe, having undergone pilot interventions within the aquatic physiotherapy department of the university, any modifications that might impact the study's execution will necessitate renewed consideration by the Ethics Committee.

*Confidentiality*

Participant study data will not be disclosed beyond the study without explicit written consent from the participants. This confidentiality is upheld through the previously approved Informed Consent Form.

*Ancillary and post-trial care*

The responsible researcher will promptly provide comprehensive support to research participants concerning potential complications and resulting implications. Similarly, considering the research's conduct within an accredited aquatic physiotherapy service, the service will consistently uphold any requisite therapeutic follow-ups after the study.

*Dissemination*

The study will be disseminated in printed and digital media, on the researcher, university, and the academic directory of health courses social media, in the Medicine Leagues, and on institutional pages.

Study status: Already done.

# Results

Ten individuals were selected for each group (IG and CG), totaling 20 participants. The participant characteristics are described in Table 3 (Underlying data),[43] along with the statistical comparison between them. The IG and CG

demonstrated similarity in all evaluated variables, with the last two being specific to individuals with Parkinson's disease (CG). It is observed that individuals with Parkinson's disease are classified with moderate motor symptoms according to the UPDRS III, with an average score of 3 on the Modified Hoehn and Yahr Scale.

The data related to the Intervention Group (IG) outcomes concerning pre and post aquatic and dry land intervention variables are described in Table 4 (Underlying data).[43] In the PD group, there was a statistically significant difference in the Sit-to-Stand test in both interventions (aquatic physiotherapy and physiotherapy on dry land), with a higher number of sit-to-stand repetitions post-intervention compared to pre-intervention. When analyzing the Timed Up and Go (TUG) test, a statistically significant difference was observed only in the dry land intervention, with a shorter test completion time post-intervention ($p = 0.021$). The same occurred when analyzing the flexibility of the posterior musculature of the lower limbs using the Wells bench test, with a significant difference in the comparison between pre and post-intervention on land, where the distance (cm) was greater post-intervention ($p = 0.011$). When analyzing the results of the self-perception mobility questionnaire, better post-intervention outcomes were observed only in the aquatic physiotherapy intervention ($p = 0.048$). When comparing the variation (pre and post) between interventions (aquatic physiotherapy and physiotherapy on dry land), no statistical difference was observed in both groups (with and without RA-type PD) in any analyzed variable.

The data related to the results of the Control Group (CG) regarding pre and post aquatic and dry land intervention variables are described in Table 5 (Underlying data).[43] In the group without PD, statistically significant differences were observed in all applied tests. When the Timed Up and Go (TUG) test was analyzed, the test completion time was shorter post both aquatic and dry land interventions, both with ($p = 0.001$). Furthermore, there was an improvement in the flexibility of the posterior musculature of the lower limbs in both interventions (aquatic $p = 0.029$; dry land $p = 0.001$), as evaluated by the Wells bench test. In the Sit-to-Stand test, the number of sit-to-stand repetitions was higher post-intervention compared to pre-intervention in both interventions (aquatic $p = 0.004$; dry land $p = 0.001$). When analyzing the results of the self-perception questionnaire of mobility and well-being, better post-aquatic intervention outcomes were observed ($p = 0.012$; $p = 0.017$ respectively) and in the well-being questionnaire post-dry land intervention ($p = 0.034$). When comparing the variation (pre and post) between interventions (aquatic physiotherapy and physiotherapy on dry land), no statistical difference was observed in both groups (with and without RA-type PD) in any analyzed variable.

The data related to the results of the self-perception questionnaire on applicability and safety, feasibility and future use of exercise protocols emphasizing the extensor musculature of the vertebral column on dry land and in shallow water are described in Table 6 (Underlying data).[43]

An excellent score (score 8 to 10 in the self-perception questionnaire) can be observed in all questions asked after the intervention (dry land and shallow water), with almost all study participants classifying the applicability and safety, feasibility and use future of the protocols as a maximum score in all questions in the questionnaire, indicating an optimal perception score.

## Discussion

This study had two main objectives. The first was to develop two exercise protocols emphasizing the extensor musculature of the vertebral column (on dry land and in shallow water) for individuals with and without rigid-akinetic type Parkinson's Disease (PD). The second main objective was to investigate the acute effects of a single session of physiotherapy on dry land and aquatic physiotherapy on the functional capacity of individuals with and without rigid-akinetic type PD, as well as to assess the applicability and safety of the aforementioned protocols.

These protocols were developed considering that one of the main motor alterations in individuals with rigid-akinetic PD is the reduction of strength in the extensor musculature of the vertebral column.[9] Therefore, the protocol focused on specific exercises for this muscle group. The diminished activation of postural stabilizing muscles of the vertebral column affects the biomechanical parameters of gait and the mobility of these individuals,[5] leading to a decrease in functional capacity such as balance, flexibility of the posterior musculature of the lower limbs, mobility, and well-being. Thus, the reduction in the force-generating capacity of the extensor musculature of the vertebral column associated with postural instability in individuals with PD[9] reinforces the importance of well-described exercise protocols to assist therapists in clinical practice and exercise selection in the rehabilitation process for this population.

Moreover, the main results of this study corroborate with the study hypothesis that the practice of exercises in different environments is important for the maintenance and improvement of functional capacity parameters in individuals with and without PD.[13,14] When comparing the variation (pre and post) between interventions (aquatic physiotherapy and physiotherapy on dry land), no statistical difference was observed in either group (with and without rigid-akinetic PD) in

any analyzed variable, indicating that both therapies – aquatic physiotherapy and physiotherapy on dry land – proved to be valuable allies in clinical practice and beneficial for individuals with and without PD. In aquatic physiotherapy, due to the influence of the hydrodynamic and hydrostatic properties of water, instability during immersion causes continuous postural adjustments,[37] making it a potential ally in the rehabilitation process and maintenance of motor skills. On the other hand, physiotherapy on dry land allows the performance of exercises closer to activities of daily living, assisting in reproducibility and execution of specific exercises for the extensor musculature of the vertebral column,[38] which is crucial for the rigid-akinetic type of PD, commonly affected by postural instability, as well as for maintaining the functional capacity of individuals unaffected by the disease. Thus, both physiotherapy on dry land and aquatic environments are important strategies in improving motor skills[13,14] in individuals with and without PD.

This study demonstrates that a single session of physiotherapy emphasizing the extensor musculature of the vertebral column, both in water and on dry land, results in improved functional capacity in both groups, as indicated by positive results in the Sit-to-Stand test, which assesses agility, balance, flexibility, and strength of the lower limbs.[39] Thus, the improvement of these parameters demonstrates the positive impact of exercise on the modulation of functional and postural alterations in individuals with and without PD.[40–42] The results of the study show that individuals without PD showed improvements in all tests assessing functional capacity after completing both protocols, while individuals with rigid-akinetic PD showed more significant results after the session of physiotherapy on dry land, demonstrating the importance of different therapeutic interventions in the rehabilitation process.[15]

Furthermore, the study demonstrates, as observed in the results of the TUG, STS, and Wells bench tests, that after a single session of physiotherapy on dry land, individuals with and without rigid-akinetic PD achieved significant results regarding functional capacity, showing improvement in balance, flexibility of the posterior musculature of the lower limbs, mobility, and well-being. In the aquatic physiotherapy intervention protocol, it was observed that after a single session, individuals from both groups showed significant results in the Sit-to-Stand test and in the self-perception mobility questionnaire, with consequent improvement in functional capacity parameters. Thus, the functional tests used in this study to assess the functional capacity of individuals with and without rigid-akinetic PD demonstrate that after a single session of different physiotherapy interventions (aquatic and on dry land), the individuals in the study benefited and showed improvements in their ability to perform their activities of daily living with better skill.

In order to develop a well-described intervention protocol, besides the concern in choosing exercises that address established therapeutic objectives, it is necessary to ensure good execution safety and clinical applicability. Thus, not only does the developed protocol emphasize improving the functional capacity of individuals with and without rigid-akinetic PD, but the study also verified through a self-perception questionnaire of applicability and safety the feasibility and future use of the aforementioned aquatic and dry land protocols. The results indicate that both exercise protocols emphasizing the extensor musculature of the vertebral column on dry land and in shallow water met the participants' expectations, who reported improvement in walking, motor condition, and cognition perception. Moreover, the protocols ensured safety and comfort during exercise execution, leading to acceptance, treatment continuity, and future recommendation of both exercise protocols. These findings enable the replication and applicability of the protocols in clinical practice, assisting the therapist and ensuring safety in the rehabilitation process.

Thus, the scarcity of well-described exercise protocols in the literature reinforces the importance of this study. Moreover, the widespread use of these interventions and their immediate responses in improving the functional capacity of individuals with and without rigid-akinetic PD reinforce the long-term use of these protocols. Therefore, the neurofunctional rehabilitation research group, of which this study is part, is conducting longitudinal studies to analyze long-term functional variables, as well as to document the intensity, training volume, and exercise evolution levels, ensuring better therapeutic management in the rehabilitation process.

The present study has some limitations. The sample consisted of a relatively small number of participants, which may weaken the robustness of the results and complicate the detection of significant differences. Additionally, the intervention was limited to a single session, preventing a thorough assessment of the long-term effects of the exercise protocols implemented. The single-blind design employed for participant responses could also introduce bias, as the lack of complete blinding might lead to expectations regarding the treatment benefits. Moreover, outcome assessments were conducted at only one point post-intervention, making it impossible to analyze the evolution of effects over time.

## Conclusions

This work consists of a protocol study followed by a subsequent randomized clinical trial with the application of a single session. The findings of the study show that a single session of physiotherapy (on dry land and in shallow water) emphasizing the extensor musculature of the vertebral column results in improvement of functional capacity parameters

such as balance, flexibility of the posterior musculature of the lower limbs, mobility, and well-being in individuals with and without rigid-akinetic type PD.

The results indicate that both protocols met the participant expectations, who reported perceived improvement in walking, motor condition, and cognition. Additionally, the protocols ensured safety and comfort during exercise execution, leading to acceptance, treatment continuity, and recommendation for future use of both exercise protocols. These findings enable the replication and applicability of the protocols in clinical practice, assisting the therapist and ensuring safety in the rehabilitation process. Moreover, the research group to which this study belongs is already conducting longitudinal studies to investigate the long-term effects of the interventions described here.

### Ethics approval and consent

This research was approved by the Research Ethics Committee of the Federal University of Health Sciences of Porto Alegre (CEP-UFCSPA) under opinion number 4.546.442, on February 18, 2021 and registered on Clinical Trials under the title "Acute Effects of Strength Training and High Intensity Training on Functional and Biochemical Measurements of Individuals With Parkinson's Disease in Different Environments and Depths," with the registry number NCT04863118. The registration date is February 9, 2024, and further details can be accessed at https://clinicaltrials.gov/study/NCT04863118. This study adheres to the principles of Resolution 466/12 of the National Health Council and follows all ethical guidelines related to research involving human participants.[35]

The study was conducted at the School of Physical Education, Physiotherapy, and Dance of the Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, RS. All participants were invited to join the study voluntarily, and informed consent was obtained in writing from each participant. The Free and Informed Written Consent Form (ICF) was used in accordance with Resolution 466/12 of the National Health Council,[36] and all participants signed this form before enrolling in the study. No waiver of consent was requested or granted by the Ethics Committee.

## Data availability

### Underlying and Extended data

Harvard Dataverse: Dataset for the Study "Effects of aquatic and dry land physiotherapy on the functional capacity in individuals with and without parkinson's disease: a protocol study followed by a randomized clinical trial". https://doi.org/10.7910/DVN/VZ6HHE.[43]

This project contains the following extended data:

- Anamnesis.xlsx
- Applicability and Safety.xlsx
- CONSORT-2010-Checklist.doc
- Figure 1.tif
- Figure 2. tif
- Figure 3.tif
- ICF.docx
- Table 1. docx
- Table 2. docx
- Table 3. docx
- Table 4. docx
- Table 5. docx

- Table 6. docx
- Well-being and Mobility.xlsx



## Software availability

The data analysis for this study was conducted using SPSS version 22.0 (IBM Corp., Armonk, NY). For readers seeking an open-source alternative, equivalent analyses can be performed using JASP (https://jasp-stats.org/) or R (https://www.r-project.org/).

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