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ARTIGO ORIGINAL

EFFECTS OF WATER AEROBICS AND DEEP WATER RUNNING ON COGNITION IN OLDER ADULTS: A PRAGMATIC STUDY

EFEITOS DA HIDROGINÁSTICA E DA CORRIDA EM PISCINA FUNDA NA COGNIÇÃO DE IDOSOS: UM ESTUDO PRAGMÁTICO

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Abstract

This study compared the effects of water aerobics (HIDRO) and deep-water running (DWR) on global cognition and cognitive domains in physically active older adults. This quasi-experimental pragmatic trial included 92 community-dwelling older adults allocated to HIDRO (n = 42) or DWR (n = 50). The intervention lasted 36 weeks, with two 45-minute sessions per week. Cognitive function was assessed before and after the intervention using the Montreal Cognitive Assessment (MoCA). Data were analyzed using Generalized Estimating Equations with Bonferroni post hoc adjustment ($\alpha < 0.05$). No significant time × group interaction was observed, indicating similar responses between groups. A significant time effect was found for the visuospatial/executive domain, with improvements in both groups ($p = 0.007$). Global cognition and the naming, attention, language, abstraction, delayed recall, and orientation domains remained stable. These findings suggest that both aquatic exercise modalities produced similar cognitive responses and may contribute to maintaining cognitive performance in physically active older adults.

KEYWORDS

Aging. Aquatic Exercise. Cognition. Physical Fitness. Endurance Training. Resistance Training.

Resumo

Este estudo comparou os efeitos da hidroginástica (HIDRO) e da corrida em águas profundas (DWR) na cognição global e em domínios cognitivos em idosos fisicamente ativos. Este ensaio pragmático quase-experimental incluiu 92 idosos residentes na comunidade, alocados para HIDRO (n = 42) ou DWR (n = 50). A intervenção teve duração de 36 semanas, com duas sessões de 45 minutos por semana. A função cognitiva foi avaliada antes e depois da intervenção utilizando o Montreal Cognitive Assessment (MoCA). Os dados foram analisados utilizando Equações de Estimação Generalizadas com ajuste post hoc de Bonferroni ($\alpha < 0,05$). Não foi observada interação significativa entre tempo e grupo, indicando respostas semelhantes entre os grupos. Um efeito significativo do tempo foi encontrado para o domínio visoespacial/executivo, com melhorias em ambos os grupos ($p = 0,007$). A cognição global e os domínios de nomeação, atenção, linguagem, abstração, recordação tardia e orientação permaneceram

estáveis. Esses resultados sugerem que ambas as modalidades de exercício aquático produziram respostas cognitivas semelhantes e podem contribuir para a manutenção do desempenho cognitivo em idosos fisicamente ativos.

PALAVRAS-CHAVE

Envelhecimento. Exercício Aquático. Cognição. Aptidão Física. Treino Aeróbico. Treinamento Resistido.

1 Introduction

The demographic transition characterized by an increasing proportion of older adults represents one of the most significant social changes of this century (UN, 2019). From a biological perspective, this process is associated with the continuous accumulation of molecular and cellular alterations, which contributes to the progressive decline of cognitive functions and an increased predisposition to the development of diseases (WHO, 2024). In addition, human aging is a universal, ubiquitous, and inevitable process, in which all physiological functions gradually decline (Izquierdo et al., 2021).

Despite increased longevity and improved quality of life, age-related cognitive decline cannot be entirely prevented (Terra de Oliveira et al., 2024). This decline particularly affects reasoning, processing speed, attention, executive function, and memory, occurring as a result of structural changes in the frontal and medial temporal lobes of the brain, including the hippocampus (Izquierdo et al., 2021). To mitigate these effects, clinical evidence indicates that physical exercise performed in an aquatic environment promotes significant benefits in cognitive function among non-institutionalized older adults (Farinha et al., 2021).

Among aerobic exercise programs performed in water, modalities such as water aerobics (HIDRO) and deep water running (DWR) stand out for the older population due to the osteoarticular safety provided by the properties of water. Water aerobics reduces joint impact forces through buoyancy, although the feet remain in contact with the ground (Andrade & Alberton, 2025). In contrast, DWR is performed in deep water with the aid of a flotation vest, being conducted in a non-weight-bearing environment that eliminates vertical ground reaction forces (Kwok et al., 2022; Andrade & Alberton, 2025). Because it is impact-free and reduces the potential risk of musculoskeletal injuries, this modality is established as a viable and safe training alternative for older individuals who may be vulnerable or have fear of falls and joint pain (Kwok et al., 2022).

Although clinical trials and systematic reviews have already demonstrated the benefits of exercise in aquatic environments, investigations using pragmatic designs are necessary to demonstrate the benefits of training within real-world contexts, such as those experienced in fitness centers and aquatic training facilities, characterizing a “real-world” approach (Leonel et al., 2024).

Given this context, the present study aimed to investigate the effects of a structured aquatic exercise program, comparing water aerobics (HIDRO) and deep-water running (DWR), on global cognition and cognitive domains in physically active older adults.

2 Methods

The study included older adults of both sexes, aged 60 years or older, who were participants in the Extension Program (no. 47828) of the Center for Reference in Aging and Movement (CREM), affiliated with the Federal University of Rio Grande do Sul (UFRGS). As inclusion criteria, participants were required to have medical clearance for physical exercise, independent ambulation, and no osteomuscular or joint limitations that could interfere with the performance of the proposed activities. The interventions were conducted at the Olympic Center on the campus of the School of Physical Education, Physiotherapy and Dance (ESEFID/UFRGS).

A prior sample size calculation was not performed, characterizing a convenience sample. Furthermore, the allocation of participants into the HIDRO and DWR groups was not randomized, but based on their personal preferences for the exercise modality and available schedules.

The study was designed as a quasi-experimental trial with a pragmatic approach. Participants were allocated into two intervention groups: HIDRO and DWR. Both groups underwent the same periodized training program, conducted twice weekly over a period of 36 weeks.

Each session lasted 45 minutes and was structured into three phases: approximately 5 minutes of warm-up, 30 minutes of the main activity, and 10 minutes of cool-down. The sessions were conducted in an aquatic environment with an average temperature of 32 °C. In the HIDRO group, participants were instructed to maintain immersion up to the level of the xiphoid process. In the DWR group, activities were performed in deep water using flotation vests, with no foot contact with the pool floor, characterizing a non-impact modality. The exercise sessions were conducted by undergraduate students in physical education, serving as scholarship recipients or volunteers, who acted as instructors and monitors under the supervision of graduate students.

Exercise intensity was continuously monitored using the Borg Rating of Perceived Exertion Scale (6–20). The training program was structured into six progressive mesocycles, incorporating alternating interval and combined methods (aerobic and resistance). A detailed description of the periodization, including effort–recovery ratios for each mesocycle, is presented in Table 1.

Table 1. Periodization Model

Mesocycle	Week	Training	Periodization
1	1-4	Aerobic Interval Training	5x (1min RPE 11+ 2min RPE 13 + 30s RPE 15 + 30s RPE 11 + 1min RPE 13)
2	5-9	Aerobic Interval Training	5x (2min RPE 13 + 30s RPE 15 + 2min RPE 13 + 30s RPE 17)
3	10-14	Combined (aerobic + strength)	6x (4min RPE 13 + 30s RPE 19 (strength - upper limb) + 30s RPE 19 (strength - lower limb)
4	15-20	Aerobic Interval Training	8x (2min RPE 13 + 30s RPE 15 + 1min RPE 13 + 30s RPE 17)
5	21-27	Aerobic Interval Training	7x (1min RPE 15 + 30s RPE 17 + 1min RPE 13 + 30s RPE 19 + 2min RPE 13)
6	28-36	Combined (aerobic + strength)	6x (2min 15 + 2min 13 + 30s 19 (strength - upper limb) + 30s RPE 19 (strength - lower limb)

min = minutes; s = seconds; RPE = rating of perceived exertion

To characterize the sample, sociodemographic data (age, sex, ethnicity, income, and educational level), clinical data (comorbidities), and anthropometric measurements (body mass, height, and body mass index) were collected.

Cognitive function was assessed using the Montreal Cognitive Assessment (MoCA), an instrument that encompasses the visuospatial/executive, naming, attention, language, abstraction, delayed recall (memory), and orientation domains, in addition to a total score representing global cognitive performance. Furthermore, given the pragmatic nature of the study, the assessors were not blinded during the evaluations.

The MoCA is a brief screening tool that has been widely validated for the detection of cognitive decline (Nasreddine et al., 2005). The test is structured to evaluate mental abilities across specific domains. The visuospatial/executive domain is assessed through a clock-drawing task, copying a three-dimensional cube, and a trail-making task. Naming is evaluated by the identification of three low-familiarity animals. Attention is measured by target detection tasks (tapping), serial subtraction, and forward and backward digit span tasks. Language is assessed through the repetition of two syntactically complex sentences and a phonemic verbal fluency task. Abstraction is evaluated using a verbal similarity task between two items. Delayed recall

(memory) is assessed by the ability to recall five previously presented nouns after a latency period. Finally, orientation is measured by the individual's correct identification of time and place. In addition, the total score, representing overall cognitive performance, is obtained by summing all tasks, with a maximum possible score of 30 points (Nasreddine et al., 2005).

The primary analysis was conducted according to the intention-to-treat principle. Sample characterization was performed using descriptive statistics, with continuous variables presented as mean and standard deviation, and categorical variables expressed as absolute and relative frequencies (%). To compare outcomes over time (pre- and post-intervention), between groups (HIDRO and DWR), and to analyze potential interactions (time × group), Generalized Estimating Equations (GEE) were employed, with Bonferroni post hoc adjustment. Additionally, absolute changes (Δ) between pre- and post-intervention time points were calculated for descriptive purposes. The level of significance was set at $\alpha < 0.05$, and all analyses were performed using IBM SPSS® software (version 25.0).

Participants were fully informed about the objectives, procedures, and potential risks of the study and formalized their participation by signing a written informed consent form. The study was conducted in accordance with the ethical principles established in the Declaration of Helsinki and was submitted to and approved by the Research Ethics Committee of the Federal University of Rio Grande do Sul (approval no. 5.993.354).

3 Results

The sample consisted of 92 participants, distributed between the HIDRO group (n = 42) and the DWR group (n = 50). A predominance of female participants was observed in both groups, with 43 individuals (95.6%) in HIDRO and 43 (86.0%) in DWR, while males accounted for 2 (4.4%) and 12 (24.0%) participants, respectively. The mean age was 74.74 years (95% CI: 72.99–76.49) in the HIDRO group and 72.24 years (95% CI: 70.61–73.87) in the DWR group. Regarding anthropometric variables, the HIDRO group presented a mean body mass of 70.31 kg (95% CI: 66.82–73.80), mean height of 154.88 cm (95% CI: 152.78–156.98), and a body mass index (BMI) of 29.17 kg/m² (95% CI: 27.88–30.45). In the DWR group, the corresponding mean values were 70.12 kg (95% CI: 66.80–73.44), 157.40 cm (95% CI: 155.17–159.63), and 28.20 kg/m² (95% CI: 27.09–29.31), respectively. In terms of income, the highest proportion was concentrated in the range of 1 to 3 minimum wages, corresponding to 19 participants (45.2%) in HIDRO and 25 (50.0%) in DWR. The remaining categories included ≤1 minimum wage (19.0% and 8.0%), 4 to 6 minimum wages (19.0% and 16.0%), 7 to 9 minimum wages (7.1% and 8.0%), and ≥10 minimum wages (7.1% and 14.0%), in addition to participants who did not report this variable. Regarding educational level, a higher frequency of secondary/technical and higher education levels was observed. In the HIDRO group, 10 participants (23.8%) had completed secondary/technical education and 20 (47.6%) had higher education, whereas in the DWR group these values corresponded to 23 (46.0%) and 24 (48.0%), respectively, with other levels being less represented. With respect to ethnicity, there was a predominance of participants self-identifying as White, totaling 40 individuals (95.2%) in HIDRO and 45 (90.0%) in DWR, with lower representation of mixed-race and Black individuals in both groups. Regarding health conditions, the most frequent comorbidities were hypertension (40.0% in HIDRO and 38.2% in DWR), osteoarthritis (35.5% and 23.6%), and anxiety (24.4% and 12.7%). Relevant prevalences of diabetes (11.1% and 20.0%) and arthritis (15.5% and 14.5%) were also observed. Other conditions, such as osteoporosis, heart disease, stroke, asthma, and cancer, were less prevalent. Notably, 8.9% of participants in the HIDRO group and 9.1% in the DWR group reported having no diagnosed diseases.

The means, 95% confidence intervals (95% CI), and absolute changes (Δ) of the cognitive domains and total score of the MoCA, at pre- and post-intervention time points, are presented in Table 2. The analysis did not reveal significant interactions for any of the assessed outcomes, including the visuospatial domain ($p = 0.259$), naming ($p = 0.625$), attention ($p = 0.937$), language ($p = 0.157$), abstraction ($p = 0.887$), delayed recall ($p = 0.284$), orientation ($p = 0.206$), and total score ($p = 0.916$). Similarly, no significant differences were observed

for the main effect of group in any of the analyzed variables, including visuospatial (p = 0.453), naming (p = 0.244), attention (p = 0.366), language (p = 0.695), abstraction (p = 0.932), delayed recall (p = 0.200), orientation (p = 0.932), and total score (p = 0.158). On the other hand, regarding the effect of time, a statistically significant difference was identified only in the visuospatial domain (p = 0.007). The remaining outcomes did not show significant changes over the intervention period, including naming (p = 0.880), attention (p = 0.058), language (p = 0.971), abstraction (p = 0.057), delayed recall (p = 0.964), orientation (p = 0.297), and total score (p = 0.100).

Table 2. Results of cognitive domains and total score (MoCA), at pre and post-intervention.

			Baseline		Post-intervention		
Outcome	Group	n	Mean	CI 95% Lower- Upper	Mean	CI 95% Lower- Upper	Δ
Visuospatial	HIDRO	42	2.91	2.53 -3.29	3.44*	3.13 - 3.75	0.53
	DWR	50	2.91	2.57 - 3.25	3.13*	2.76 - 3.49	0.22
Naming	HIDRO	42	2.75	2.62 - 2.88	2.73	2.57 - 2.90	-0.02
	DWR	50	2.60	2.42 - 2.79	2.64	2.48 - 2.80	0.04
Attention	HIDRO	42	4.64	4.27 - 5.02	4.29	3.78 - 4.80	-0.35
	DWR	50	4.38	3.98 - 4.79	4.05	3.54 - 4.57	-0.33
Language	HIDRO	42	1.96	1.69 - 2.22	2.11	1.83 - 2.39	0.15
	DWR	50	2.05	1.82 - 2.29	1.89	1.61 - 2.17	-0.16
Abstraction	HIDRO	42	1.80	1.65 - 1.94	1.90	1.79 - 2.02	0.10
	DWR	50	1.79	1.65 - 1.93	1.92	1.84 - 1.99	0.13
Delayed Recall	HIDRO	42	4.20	3.89 - 4.52	4.07	3.67 - 4.48	-0.13
	DWR	50	3.77	3.45 - 4.09	3.92	3.51 - 4.32	0.15
Orientation	HIDRO	42	5.82	5.69 -5.95	5.80	5.67 5.94	-0.02
	DWR	50	5.74	5.59 -5.89	5.88	5.78 - 5.97	0.14
Total Score	HIDRO	42	24.93	24.06 - 25.80	25.49	24.56 - 26.42	0.56
	DWR	50	24.09	23.11 - 25.08	24.58	23.53 - 25.64	0.49

MoCA = Montreal Cognitive Assessment; HIDRO = Water Aerobics group; DWR = Deep Water Running group; CI 95% = 95% Confidence Interval; Δ = Delta; * Significant difference over time (p < 0.05).

4 Discussion

The main findings of the present study demonstrate that both aquatic exercise modalities promoted improvements in the visuospatial domain among physically active older adults. For global cognition and the other evaluated domains (naming, attention, language, abstraction, delayed recall, and orientation), performance was maintained over the 36-week intervention period, with no differences observed between water aerobics and deep water running.

Regarding the improvement observed in both groups in the visuospatial domain, the increase in blood flow and shear stress within the vasculature (particularly during water immersion) may serve as an important stimulus for endothelial and cerebrovascular adaptations, with potential benefits for brain health (Carter et al., 2014; Parfitt et al., 2017). These effects appear to be associated, at a systemic level, with the release of exercise-induced myokines, such as BDNF and IGF-1, which play a relevant role in the communication between skeletal muscle and the brain, modulating cognitive function through autocrine and paracrine pathways (Bae & Song, 2019).

The absence of significant differences between the groups (HIDRO and DWR) suggests that the observed responses were primarily related to the similarly structured physical exercise performed by both groups, regardless of the specificity of the motor task. Likewise, the absence of significant gains in global cognition and the remaining domains indicates that exercise-induced neurological adaptations occur in a complex and gradual manner during aging. Although the literature reports positive effects of aquatic exercise on cognition (Campos et al., 2021; Dunlap et al., 2024; Kang et al., 2020), evidence suggests that such adaptations are more pronounced when combined with specific cognitive stimuli during practice (Meekum et al., 2025). Recent studies have demonstrated that interventions combining motor and cognitive tasks in aquatic environments promote broader benefits, with the incorporation of concurrent cognitive challenges during exercise representing an important component for mental stimulation (Terra de Oliveira et al., 2024). Furthermore, Meekum et al. (2025) observed that exercise combined with cognitive training is more effective than exercise alone in enhancing overall cognitive performance, particularly in complex executive functions such as cognitive flexibility and task switching. Therefore, the absence of a specifically targeted cognitive task within the intervention protocol may explain the stability observed in the remaining cognitive domains.

Nevertheless, the findings of the present study hold clinical relevance, as cognitive performance remained stable during the intervention period of these variables over time. Taken together, the data reinforce the role of physical exercise in preserving cognitive function in healthy older adults. The maintenance of these levels through exercise is particularly relevant in the context of aging, given that regular practice is associated with the attenuation of cognitive decline (Bento-Torres et al., 2019), thereby constituting an essential strategy for preserving independence, functionality, and quality of life, even in the absence of additional cognitive stimulation (Rossi et al., 2021).

Furthermore, this study presents limitations that should be considered. As a pragmatic, real-world study, the absence of randomization and a control group reduces internal validity and limits causal inferences regarding the observed cognitive outcomes. The absence of effect size measures also restricts the interpretation of the magnitude of the interventions. Regarding sample characteristics, there was no strict control over participants' activities of daily living, and the individuals assessed were not sedentary, but rather physically active and already enrolled in the program since 2022. This context may have contributed to a potential ceiling effect, thereby reducing additional responses to training. Furthermore, the results specifically refer to the investigated sample, reflecting limited external validity and restricting the generalizability of the findings. Additionally, the absence of cognitive tasks associated with the interventions, combined with the predominantly motor-based nature of the training, may have limited more pronounced gains in cognitive outcomes. Finally, the relatively low weekly training frequency may not have provided a sufficient stimulus to promote more robust changes in complex cognitive variables.

5 Conclusion

The findings suggest that a structured aquatic exercise program incorporating interval aerobic and combined training, whether water aerobics or deep water running, contributes to the maintenance of global cognition in physically active older adults. Furthermore, both interventions are associated with improvements in executive function, specifically in the visuospatial domain. Despite the methodological limitations, the regular and pragmatic practice of these modalities represents a viable non-pharmacological strategy for preserving neurological health during aging.

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