Original Article

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Effectiveness of aquatic and non-aquatic lower limb muscles endurance training in the static and dynamic balance of elderly people

Efetividade do treinamento de resistência à fadiga dos músculos dos membros inferiores dentro e fora d'água no equilíbrio estático e dinâmico de idosos

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Abstract

Background: Aging compromises the ability of the central nervous system to maintain body balance and reduces the capacity for adaptive reactions. To prevent falls, the reception conditions for sensory information need to be improved. **Objectives:** To evaluate the impact of a structured aquatic and a non-aquatic exercise program for lower-limb muscle endurance on the static and dynamic balance of elderly people. **Methods:** This was a prospective randomized clinical study in which the variables were assessed before and after the training program. Thirty-six elderly people were evaluated using four tests: the Berg Balance Scale, Dynamic Gait Index, gait speed and tandem gait. The participants were randomized into three groups: aquatic exercise group, non-aquatic exercise group and control group. The exercise groups underwent a program for lower-limb muscle endurance that consisted of 40-minute sessions twice a week for six weeks. The participants were reevaluated after six weeks. The data were analyzed statistically using the univariate ANOVA test for comparisons between the groups before and after the intervention. **Results:** The program for lower-limb muscle endurance significantly increased balance ($p<0.05$) in the evaluation tests after the training program. **Conclusion:** The muscle endurance program provided a significant improvement in static and dynamic balance among community-dwelling elderly people. It was also possible to infer that this improvement occurred regardless of the environment, i.e. aquatic or non-aquatic.
Article registered in the Australian New Zealand Clinical Trials Registry (ANZCTR) under the number ACTRN 12609000780257.

Key words: hydrotherapy; physical therapy; elderly people.

Resumo

Contextualização: O envelhecimento compromete a habilidade do sistema nervoso central (SNC) de realizar a manutenção do equilíbrio corporal bem como diminui a capacidade das reações adaptativas. Para prevenir as quedas, é necessário aprimorar as condições de recepção de informações sensoriais. **Objetivos:** Comparar o impacto de um programa estruturado de exercícios de resistência muscular dos membros inferiores dentro e fora d'água no equilíbrio estático e dinâmico em idosos. **Métodos:** Trata-se de um estudo clínico, prospectivo, aleatório, em que as variáveis utilizadas foram avaliadas antes e após o programa de treinamento. Foram avaliados 36 idosos por meio de quatro testes: Escala de Equilíbrio de Berg, *Dynamic Gait Index*, velocidade da marcha, Marcha *Tandem*. Posteriormente, houve a alocação dos voluntários em três grupos: grupo de exercício na piscina terapêutica, grupo de exercício no solo e grupo controle. Os grupos de exercícios foram submetidos a um programa de resistência muscular dos membros inferiores aplicado durante seis semanas, duas sessões semanais com 40 minutos de duração. Os voluntários foram reavaliados após seis semanas. Os dados foram analisados estatisticamente pelo teste ANOVA univariada para comparação entre os três grupos antes e após a intervenção. **Resultados:** O programa de resistência muscular dos membros inferiores promoveu aumento significativo do equilíbrio dos idosos ($p<0,05$) nos testes avaliados após o programa de treinamento. **Conclusão:** O programa de resistência muscular proporcionou uma melhora significativa no equilíbrio estático e dinâmico de idosos comunitários. Foi possível inferir também que essa melhora ocorreu independentemente do meio em que o programa foi realizado, ou seja, se dentro ou fora d'água.
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Palavras-chave: hidroterapia; fisioterapia; idosos.

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Introduction

Improvement of health conditions, increasing life expectancy worldwide and birth rate reductions have brought about a proportional increase in the older population[1-3]. Ageing compromises the ability of the central nervous system to carry out processing on the vestibular, visual and proprioceptive signals that are responsible for the maintenance of body balance, as well as reducing individuals' capacity to come up with adaptive reactions[1]. Postural instability is one of the main factors that limit older individuals' daily activities, and falling is the most harmful consequence of this process, thereby limiting functional mobility and rendering older adults more dependent[4].

In order to prevent falls, the conditions under which sensory information is received from the vestibular, visual and somatosensory systems need to be improved in such a way that the muscles of the effector system are activated and balance is stimulated[5,6], one of the means adopted to promote such stimuli is physical exercise[7]. This reduces the risk of falls among older adults through enhancing coordination and balance[8], increasing the recruitment of motor neurons and boosting the resistance to muscle fatigue and hypertrophy, particularly of type II fibers[9].

Most studies in the literature have shown improvements in older patients' balance through multifactorial interventions, including balance[10,11], muscle endurance[9,11] or muscle strengthening[11-13] exercises, or an association between these[8-10] Studies that assess the effect of muscle endurance training alone on balance are rare[9,11].

Muscle endurance exercises may be carried out in an aquatic environment, as well as on the floor[9-11]. Aquatic exercises make it possible to create situations of instability by using effects such as turbulence, providing a great amount of sensory information, which in turn promotes improvement in body balance reactions[14,15,17-20]. On the other hand, exercises performed in a non-aquatic environment are closer to activities of daily living activities, since they do not cancel out the force of gravity[9-13]. However, there are no studies in the literature comparing the effectiveness of muscle endurance training in aquatic and non-aquatic environments. Hence, this study had the objective of comparing the impact of structured exercise programs to test lower-limb muscle endurance in aquatic and non-aquatic environments, in situations of static and dynamic balance, involving older adults.

Methods

This was a prospective, randomized clinical study in which the variables used were evaluated before and after the training program. This study was conducted in accordance with the ethical principles for research involving human beings, as prescribed by Resolution 196/96 from the National Health Board (Conselho Nacional de Saúde). It received approval from the Research Ethics Committee of the Universidade Federal dos Vales do Jequitinhonha e Mucuri (UFVJM), Diamantina (MG), Brazil (protocol no. 020/08). The participants received information about the study and signed a free and informed consent statement.

A pilot study was carried out to check the feasibility of the investigation and to monitor the entire data collection process. The volunteers in this specific group (n=10) were not included in the treatment together with the other subjects, and there were no problems during the process.

Sample

The sample for this study was made up of elderly volunteers from the community, who lived in the city of Diamantina, Minas Gerais, Brazil. They were recruited through the Family Health Program (Programa de Saúde da Família – PSF).

All the selected participants met the following inclusion requirements: 60 years of age or older, and able to perform the *Get Up and Go Test*[19]. The exclusion criteria were: individuals undergoing physical therapy treatments; those who had respiratory diseases or heart or metabolic diseases; those with a cognitive deficit according to the Mini-Mental State Examination (MMSE)[20]; those who had contagious skin abnormalities; those who were using lower limb prostheses; those who made use of drugs or medicines that might interfere with balance (nicotine, caffeine, alcohol, sedatives and tranquilizers); and those who had no anal or vesical sphincter control.

The volunteers who fulfilled the inclusion criteria made up the final sample (n=46), and these individuals were distributed randomly among the groups that were assigned to the therapeutic pool intervention (n=14), non-aquatic intervention (n=15) and control group (n=17). The intervention groups performed the protocol twice a week for six weeks, while the control group did not have any specific kind of treatment, with only a weekly follow-up by telephone.

Assessment instruments

- Dynamic gait index (DGI) (Brazilian version): This is a functional assessment test on mobility among elderly patients with balance impairments, which was validated by Shumway-Cook and transculturally adapted for application in Brazil[2]. The test is made up of 14 tasks, and each of them is categorized on a five-point ordinal scale. It has the aim of assessing and documenting patients' capacity to modify their gait according to changes in the demands of certain tasks. The maximum score is 24 points, and a score of 19 or lower suggests a risk of falls[2].

- Berg Balance Scale: This is an instrument for functional assessment of balance that has been validated and adapted transculturally for application in Brazil[21-23]. The test is made up of 14 tasks and each them is categorized on a five-point ordinal scale ranging from 0 (unable to perform the task) to 4 (able to carry out the task independently), based on the quality of the performance, need for assistance and time taken to complete the task. The scores from the 14 tasks are summed to form a total score going from 0 to 56 points, such that the highest scores correlate with the best performance.
- Tandem gait test: This test assesses patients' dynamic balance. They are required to walk in a straight line, such that the heel of the non-dominant foot is placed in front of the toes of the other foot. The performance in this test is interpreted as good when the subject is able to walk more than ten steps in a straight line; the subject is considered to have feelings of fear and uneasiness when he/she takes between two and ten steps; and the performance is poor when less than two steps are taken in a straight line[24].
- Gait speed test: the normal gait speed was measured by using a digital stopwatch. The volunteers were told to walk along a 10-meter path and the time taken was recorded, although the first two and the last two meters were left out of the calculation, in order to exclude speed variation during the acceleration and deceleration phases, respectively. The gait speed was calculated by dividing these 6-meters by the time taken to cover this distance along the path[25].

Procedures

The volunteers received a detailed explanation about the objectives and procedures of the study and signed a free and informed consent statement. Clinical and demographic data were collected by means of an evaluative questionnaire. The MMSE and some physical tests, namely the DGI, Berg Balance Scale, Tandem gait and Gait speed tests, were applied to the participants.

The next step consisted of randomly distributing the volunteers into three groups: an intervention group that received aquatic physical therapy treatment (AG), a non-aquatic intervention group (NAG) and a control group (CG). The appraisers had no access to the allocation of the volunteers to the groups. The AG underwent muscle endurance training in the physical therapy pool, twice a week, for six weeks. The NAG underwent muscle endurance training in the physical therapy gym twice a week, for six weeks. The CG did not receive any kind of physical therapy intervention during the six weeks of the study. In order to further ensure that the latter group's condition was maintained, weekly phone calls (six calls) were made to each participant, in order to follow up their daily activities.

Intervention

The structured muscle endurance program for the lower limbs consisted of a series of muscle endurance exercises for the lower limbs, carried out twice a week, every other day, for six weeks in a row. These exercises were similar for both the non-aquatic and therapy pool groups, differing only in relation to the environment in which they were being performed. The program, with the positions and activities that were carried out, is described below:

Phase I – warming up

Walking: gait with progressive speed, up to 3 minutes.

Stretching (the stretching positions were sustained for 30 seconds):

Stretching of the hamstring muscles

Position in the pool and on the floor: orthostatic position with the back resting against the wall.

Activity in the pool: to lift one of the lower limbs, while maintaining knee extension and ankle dorsiflexion.

Activity on the floor: to perform spinal flexion, while keeping the lower limbs stretched out.

Stretching of the rectus femoris and iliopsoas muscles

Position in the pool and on the floor: orthostatic position with both hands resting on the edge of the pool or against the wall, respectively.

Activity in the pool and on the floor: to perform knee flexion, sustaining it with the aid of the ipsilateral upper limb, in association with hip extension.

Phase II – muscle endurance exercises

Exercise 1: endurance exercise for the anterior muscles of the thigh

Position in the pool and on the floor: orthostatic position with the back resting against the wall.

Activity in the pool and on land: to perform hip flexion with knee extension (4x20).

Exercise 2: endurance exercise for the posterior muscles of the thigh

Position in the pool and on the floor: orthostatic position with the hands resting on the edge of the pool, or against the wall, respectively.

Activity in the pool and on the floor: to perform hip flexion with knee extension, while keeping the spine straight (4x20).

Exercise 3: endurance exercise for the lateral muscles of the thigh

Position in the pool and on the floor: orthostatic position, perpendicular to the supporting edge, with the hands resting on the edge of the pool or wall, respectively.

Activity in the pool and on the floor: to perform hip abduction, while avoiding any spinal movement (4x20).

Exercise 4: endurance exercise for the medial muscles of the thigh

Position in the pool and on the floor: orthostatic position, perpendicular to the supporting edge, with the hands resting on the edge of the pool or wall, respectively.

Activity in the pool: to perform adduction (return from the abduction) of the hip, while avoiding any spinal movement (4x20).

Activity on the floor: to perform adduction beyond the median line, while preventing the spine from moving (4x20).

Exercise 5: endurance exercise for triple flexion of the lower limbs

Position in the pool and on the floor: orthostatic position with the back resting against the wall.

Activity in the pool and on the floor: to perform triple flexion of the hips, knees and ankles (4x20).

Exercise 6: endurance exercise for the plantar flexors

Position in the pool and on the floor: orthostatic position facing the edge of the pool or wall, respectively, with support only in the event of lack of balance.

Activity in the pool and on the floor: plantar flexion in association with knee extension (4x20).

Exercise 7: endurance exercise for dorsiflexors

Activity in the pool and on the floor: to perform gait while standing on heels (three series lasting one minute each with a 30-second interval between them).

Phase III – cooling down

Walking

Activity in the pool and on the floor: gait with regressive speed, for up to three minutes.

Statistical analysis

The SPSS 11.0 software was used to analyze the data. For the quantitative variables, central tendency and variability measurements (mean, median, SD, minimum and maximum) were used. For the nominal variables, a frequency distribution table was produced. The Shapiro-Wilk test was applied to investigate whether the data was normally distributed. For multiple comparisons between the groups before and after the intervention, we used the univariate ANOVA test with Tukey's post-hoc test to identify the differences between the groups. It was decided to analyze the data by means of parametric analysis, because the data had normal distribution. Furthermore, the Kruskal-Wallis test was used to compare the category variables of sex and incidence of falls between the groups. In all the analyses, the significance level was set at 5%.

Results

Among the 46 older adults initially selected, 36 completed the study and were reevaluated after six weeks. Two participants in the AG group had to discontinue their treatment due to health problems; one in the NAG moved to another town, and seven individuals in the CG abandoned the study.

The participants' mean age was 69 years (SD=5.6; range 60–80) in the NAG, 68 years (SD=5.7; range 62–78) in the AG and 71 years (SD=3.9; range 65–78) in the CG. There was no significant age difference among the groups ($p=0.402$). The proportion of male subjects was significantly larger in the AG, comprising 64% ($p<0.05$), whereas the NAG and CG consisted mainly of female individuals (respectively, 83% and 70%). The AG and CG reported greater incidence of falls; however, there was no statistically significant difference among the groups ($p>0.05$).

Figure 1 represents the test measurements: a) Berg Balance Scale; b) DGI; c) Tandem gait; and d) Gait speed before and after the intervention. No variables showed differences between the groups before the intervention, thus indicating that the sample was homogeneous (Table 1). After the intervention, only the DGI and Berg variables showed significant differences between the intervention groups and the CG (Table 2). There was no significant difference between the therapies carried out in the non-aquatic and aquatic environments (Figure 1).

Discussion

The objective of this study was to investigate whether a lower-limb muscle strengthening program, conducted either in an aquatic or in a non-aquatic environment, would be capable of improving older adults' static and dynamic balance. In order to test our hypothesis, we used exercises that were easy to reproduce and to apply, with specifications relating to the frequency and duration of each exercise. This makes it possible to replicate this experiment in order to confirm the efficacy of the muscle training program for the static and dynamic balance of older people.

The sample was made up mainly of older women with a history of falls. This sample composition may be seen in several other studies[10,12,15,17,18,26,27], thereby corroborating the literature, since functional limitations occur more frequently among women, and they report suffering from a greater number of chronic conditions[28].

The results from the present investigation show that the training proposed was capable of improving the static and dynamic balance of older people. Likewise, other studies had shown that muscle training has a positive impact on balance among older adults[8,9,11,13,18]. Our training protocol had a frequency of twice a week, for a period of six straight weeks. There is evidence that two or three times a week is a frequency that results in significant improvements in muscle endurance, balance and functional performance, and it also reduces the number of falls[8,25]. In addition to this, the minimum duration of a training program is thought to be between six and eight weeks, i.e. the time needed to surmount the motor learning and neural adaptation phases, which are the phases mainly responsible for the production of strength and endurance during the first weeks of a training program[25].

Several studies have used physical exercise to improve older adults' static and dynamic balance[26-31]. Ballard et al.[32] looked into the effect of a program of exercises and measures to reduce falling among 40 community-living older women. The experimental group performed exercises in sessions that lasted one hour, three times a week, for 15 weeks. Among the activities, they underwent aerobic exercises and exercises to strengthen the lower limbs with elastic resistance. The volunteers were evaluated on the Berg Balance Scale, to measure their balance, and by means of a test referred to as *Wall-sit*, to measure their muscle endurance. The results from their study showed that their muscle endurance had increased significantly and that the participants' body balance had improved.

The Berg Balance Scale is an instrument that is very frequently used both in clinical practice and in research work to assess dynamic and static balance. In the present study, we observed that the groups that underwent the muscle endurance test improved their mean score on this scale. Similar data, in which it was observed that training and balance programs improve the scores on this scale, are found in the literature[11,14,30-32]. In the experiment conducted by Hess and Woollacott[33], a muscle endurance program lasting only ten weeks provided an improvement in older adults' balance that was made evident by significantly higher scores on the Berg Balance Scale.

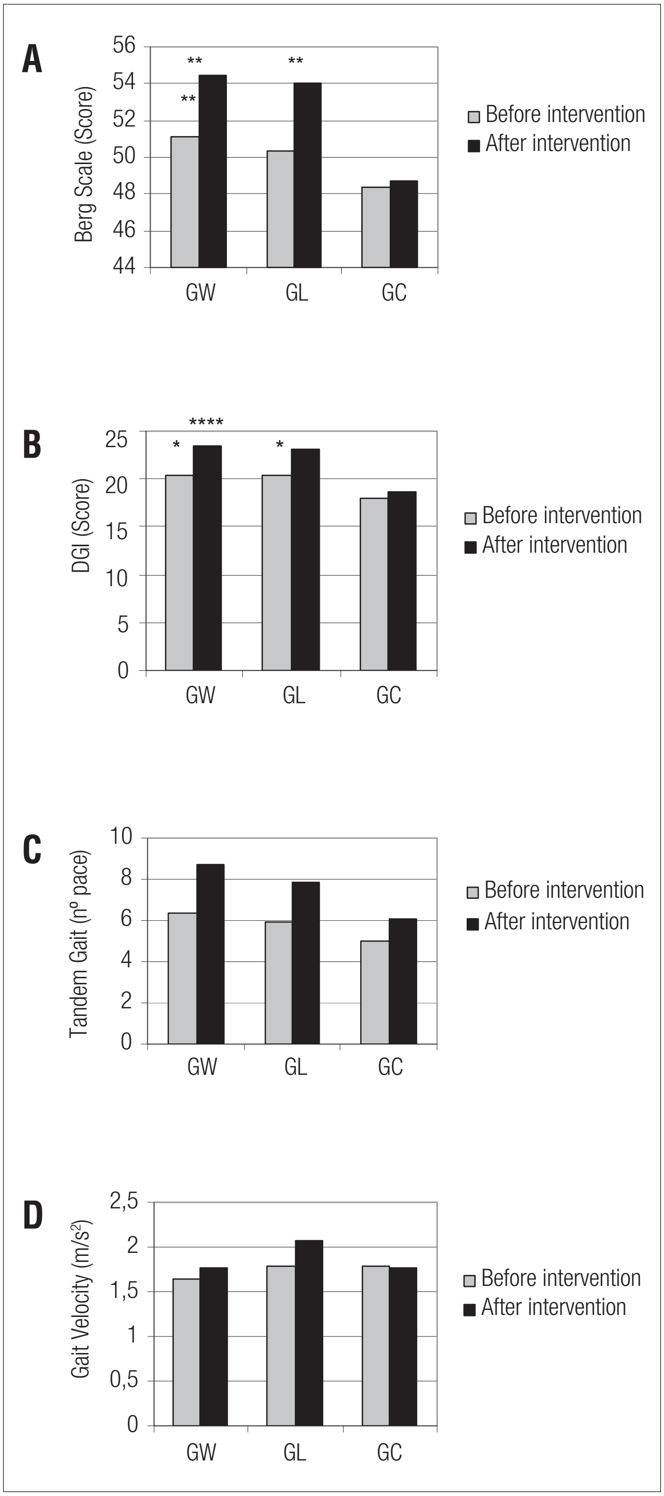

Figure 1. Medium values of the static and dynamic balance appraised for the instruments: A) Berg Scale; B) DGI; C) Tandem Gait; D) Gait Velocity in elderly in Water Group (GW), Land Group (GL) and Control Group (GC).

In the present study, there were no improvements in the older people's static or dynamic balance according to the Tandem gait test. As reported by Pereira[34], the Tandem gait test is one in which the elderly population has a weak performance. Therefore, we believe that it was not sensitive

Table 1. Tests *Post Hoc* among the groups in the moment before the intervention (n=36).

Dependent variable		I	II	Pattern error	Trust interval		Sig
					Inf	Sup	
DGI	Tukey	Land	Water	1.59	-3.97	3.85	0.999
			Cont	1.68	-1.76	6.47	0.350
		Water	Land	1.59	-3.85	3.97	0.999
			Cont	1.73	-1.84	6.67	0.356
		Cont	Land	1.68	-6.47	1.76	0.350
			Water	1.73	-6.67	1.84	0.356
Berg Sacle	Tukey	Land	Water	1.88	-5.35	3.89	0.922
			Cont	1.98	-2.91	6.82	0.590
		Water	Land	1.88	-3.89	5.35	0.922
			Cont	2.05	-2.35	7.71	0.400
		Cont	Land	1.98	-6.82	2.91	0.590
			Water	2.05	-7.71	2.35	0.400
Tandem Gait	Tukey	Land	Water	1.53	-4.15	3.34	0.962
			Cont	1.61	-3.02	4.87	0.833
		Water	Land	1.53	-3.34	4.15	0.962
			Cont	1.66	-2.75	5.41	0.704
		Cont	Land	1.61	-4.87	3.02	0.833
			Water	1.66	-5.41	2.75	0.704
Gait Velocity	Tukey	Land	Water	0.16	-0.29	0.49	0.810
			Cont	0.17	-0.31	0.53	0.792
		Water	Land	0.16	-0.49	0.29	0.810
			Cont	0.17	-0.41	0.44	0.997
		Cont	Land	0.17	-0.53	0.31	0.792
			Water	0.17	-0.44	0.41	0.997

Table 2. Tests *Post Hoc* among the groups in the moment after the intervention (n=36).

Dependent variable		I	II	Pattern error	Trust interval		Sig
					Inf	Sup	
DGI	Tukey	Land	Water	1.13	-3.05	2.50	0.968
			Cont	1.19*	1.62	7.46	0.002
		Water	Land	1.13	-2.50	3.05	0.968
			Cont	1.23*	1.79	7.84	0.001
		Cont	Land	1.19*	-7.46	-1.62	0.002
			Water	1.23*	-7.84	-1.79	0.001
Berg Scale	Tukey	Land	Water	1.61	-4.37	3.54	0.964
			Cont	1.69*	1.13	9.47	0.010
		Water	Land	1.61	-3.54	4.37	0.964
			Cont	1.75*	1.41	10.02	0.007
		Cont	Land	1.69*	-9.47	-1.13	0.010
			Water	1.75*	-10.02	-1.41	0.007
Tandem Gait	Tukey	Land	Water	1.31	-4.11	2.32	0.776
			Cont	1.38	-1.63	5.14	0.420
		Water	Land	1.31	-2.32	4.11	0.776
			Cont	1.43	-0.85	6.15	0.168
		Cont	Land	1.38	-5.14	1.63	0.420
			Water	1.43	-6.15	0.85	0.168
Gait Velocity	Tukey	Land	Water	0.18	-0.21	0.70	0.389
			Cont	0.20	-0.12	0.86	0.169
		Water	Land	0.18	-0.70	0.21	0.389
			Cont	0.20	-0.38	0.63	0.814
		Cont	Land	0.20	-0.86	0.12	0.169
			Water	0.20	-0.63	0.38	0.814

enough to detect any improvements in the body balance of these older adults.

The results from this study showed that the training protocol was not capable of improving the volunteers' gait speed. Our finding contrasts with studies in the recent literature[25,35]. Britto et al.[35] observed a significant improvement in individuals' gait speed and balance after eight weeks of aerobic training and muscle endurance exercises. However, our endurance training program prioritized training at slow motion speed, whereas static balance calls for quick muscle contractions.

We also observed a significant increase in the static and dynamic balance of the older adults who underwent the training protocols in the therapy pool. There is a growing trend within the clinical environment to indicate aquatic exercises for individuals who are afraid of, or who are at risk of falling[13-17]. Resende, Rassi and Viana[14] implemented a program of aquatic physical therapy for older women, lasting for 12 weeks, twice a week. The program, which was intended to improve balance, included activities for adaptation to the aquatic environment, hydrokinesiotherapy and aquatic exercises that defied balance. The results from their study suggested that the program of aquatic physical therapy exercises provided an increase in balance and a reduction in the risk of falls among older women.

We did not observe any significant differences in balance improvement between the intervention groups in the aquatic and non-aquatic environments. This result differs from what was found by Lund et al.[13], who compared the efficacy of aquatic and non-aquatic exercise programs on the body balance of elderly patients and observed that the aquatic exercises were significantly better for their balance than were the non-aquatic exercises. Nevertheless, it is important to highlight that the subjects of that study suffered from osteoarthritis in their knees, thus differing from our sample.

Although our sample was small, it showed that a program of exercises to develop endurance of the lower limb muscles, both in aquatic and in non-aquatic environments, provided a significant improvement in the static and dynamic movement of these community-living elderly people. Therefore, this endurance protocol may be used to improve the static and dynamic balance of older adults. Moreover, it can be concluded that aquatic muscle endurance training may be used as an alternative to conventional physical therapy treatment.

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