

ORIGINAL RESEARCH

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Effects of explosive and impact exercises on gait parameters in elderly women

Efectos de los ejercicios explosivos y de impacto sobre los parámetros de la marcha en adultas mayores

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| Abstract |

Introduction: Several systematic reviews and meta-analyses have suggested that physical activity programs combining low impact exercises and resistance exercises help maintaining functional capacity in older adults.

Objective: To analyze the effects of an aquatic training program involving both impact and explosive exercises on gait parameters of women aged 60 and above.

Materials and methods: 60 physically active women (64.08 ± 3.98 years) were divided into 2 groups: those training in a pool by performing series of jumps, i.e., the experimental group (EG=35), and the control group (CG=35). EG participants trained 3 times per week during 32 weeks in an hour per session basis. Body composition measurements, explosive strength, and gait parameters (in a 6 meters long track) were assessed using the center of pressure (COP) indicator before and after participating in the training program.

Results: When comparing both groups, differences in explosive strength and power (EG vs. CG; p values=from 0.05 to 0.001) were observed, as well as changes in gait parameters related to the COP (EG vs. CG: $p = 0.05-0.001$), in particular EG participants had significant and positive changes.

Conclusion: The aquatic training program described here produced an increase in muscle strength and muscle power, thus gait parameters were improved. Bearing this in mind, an improved availability of similar programs for older adults should be considered, since their participation in these programs could help them improve their functional capacity, and, thus, their quality of life.

Keywords: Muscle Strength; Elderly; Gait Disorder; Fitness; Locomotion (MeSH).

| Resumen |

Introducción. Varias revisiones sistemáticas y meta-análisis han sugerido que los programas de actividad física que combinan ejercicios de bajo impacto y de fuerza mantienen la capacidad funcional en adultos mayores.

Objetivo. Analizar el efecto de un programa de entrenamiento acuático basado en movimientos explosivos y de impacto en los parámetros de la marcha en adultas mayores.

Materiales y métodos. 60 mujeres físicamente activas (64.08 ± 3.98 años) fueron divididas en dos grupos, uno control (CG=35) y otro de intervención (entrenamiento en piscina usando multisaltos) (IG=35). El IG entrenó por 32 semanas, 3 días a la semana, 1 hora por sesión. Se evaluó la composición corporal, la fuerza explosiva y los parámetros de la marcha sobre 6m de recorrido usando el centro de presión (COP) antes y después de participar en el programa.

Resultados. Se presentaron diferencias en la fuerza explosiva y la potencia (EG vs. CG; $p=0.05-0.001$), así como cambios en los parámetros de la marcha relacionados al COP (EG vs. CG: $p=0.05-0.001$), con cambios significativos y positivos para EG.

Conclusión. El programa de entrenamiento en agua con movimientos de impacto y explosivos induce ganancias en fuerza muscular y potencia, lo que mejora la capacidad de caminar. Teniendo en cuenta lo anterior, se debe considerar ofrecer una mejor disponibilidad de programas similares a esta población, ya que su participación en estos programas podría ayudarles a mejorar su capacidad funcional y, por tanto, su calidad de vida.

Palabras clave: Fuerza muscular; Envejecimiento; Marcha; Aptitud; Locomoción (DeCS).

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Introduction

Considering that functional capacity in the elderly declines over time and that conditions associated with falls and fractures (1,2) such as reduced lower limb strength (70%), loss of neuromuscular coordination (90%), and reduced aerobic resistance (45%) (3) may arise, morbidity and mortality rates associated with functional impairment have increased, accounting for a 50% increased risk of acute and chronic fall-related injuries and the resulting multiplication of health care costs. (4,5)

Regarding physical exercise in older adults, some studies suggest the positive effect these models have on their gait patterns when multicomponent (strength, endurance and balance) (6-8), strength (9,10) or yoga activities are used (11), while other studies have reported that there are not significant changes when equilibrium and/or proprioception exercises are used. (12) The above evidence describes positive but heterogeneous gains that could be explained by physical activity content, environmental conditions, scheduling variables, total intervention time and evaluation procedures.

Alternatively, some authors have proposed impact and explosive movements as a valuable alternative for improving different expressions of strength that causes differentiated results in relation to gait performance in people aged 60 or over. These studies emphasize on three sets of contents that affect the walking and/or speed phases, such as the use of jumps or bounces combined with high and low intensity workouts with respect to body weight (13,14), isokinetic devices that allow controlling the speed applied at a preselected angle (15), as well as with multistation machines whose designs allow controlling the execution technique, the mobilized load and the range of articular mobility. (16) On the other hand, when physical activity programs with similar characteristics to those mentioned above have been carried out in water environments (therapeutic swimming pools), gains in lower limb strength that affect the walking pattern (17-19), specifically the speed indicator, have been reported.

However, gait speed is generally used to assess the impact of physical intervention programs on the capacity and quality of older adults' gait pattern. This is a general parameter that does not allow noticing the adjustments in the center of masses (COM), the center of pressure (COP) or the basic indicators that make up each phase of movement (e.g. speed of movement, duration, amplitude, double support, contact phase and propulsion). (20-22)

Although the speed of movement in the gait cycle allows observing functional deterioration, it cannot fully explain the multiple causal factors that may alter gait in older adults, where changes in the quantity and quality of lean muscle mass, expressions of tension in lower limbs such as explosive force and maximum isometric force, the deterioration of agonist/antagonist coordination processes involved in each movement, among other factors, affect the cognitive, nervous and muscular control of movement. (23,24)

Taking this into account, the objective of the present study was to analyze the effects an aquatic training program involving both impact and explosive exercises has on gait parameters of women aged 60 and above.

Materials and methods

A randomized study was conducted in accordance with the Consolidated Standards of Reporting Trials (CONSORT) guidelines for non-pharmacological treatments. (25) A pre and post-test design with a control group was used.

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Selection process

Participants were selected from senior recreation centers and were provided with detailed information on the project, its objectives, participation risks, the procedures to be carried out and associated risks, as well as the confidentiality measures to be implemented to ensure their data and anonymity protection. In addition, all costs related with the implementation of the program, results interpretation and the provision of physical activity recommendations based on each participant's results were borne by the biomedical team conducting the study.

Eligibility criteria

The sample consisted of women aged 60 or over who were active members of leisure and recreation activities groups.

Inclusion criteria

- Being physically active (performing 2-3 working out sessions per week without any specific objective or training plan); and
- Being clinical and functionally capable to engage in physical activity.

Exclusion criteria

- Having spine or upper or lower limbs deformities.
- Having undergone limb amputations or using prostheses.
- Using medications that may negatively or positively affect physical condition.
- Being diagnosed with cardiovascular diseases (e.g., angina pectoris, heart failure, chronic venous insufficiency).
- Suffering from articular cartilage lesions making physical activity practice impossible.
- Using drugs prescribed for osteoporosis treatment.
- Chronic use of corticosteroids.
- Calcium consumption over 1000 mg/day.
- Any kind of physical limitation observed in the additional clinical assessment.

Ethical considerations

All procedures carried out in this study complied with the ethical principles on human experimentation established in the Declaration of Helsinki (26) and Resolution 8430 of 1993, issued by the Colombian Ministry of Health. (27) In addition, all protocols and procedures in the present study were authorized by the Research Bioethics Committee of Universidad Manuela Beltrán (Date: February 25, 2015. Code: 02-25022015). All participants signed a written informed consent and then underwent a clinical and functional assessment, which ensured eligibility conditions were met, as well as the control of potential health risks.

Sampling and selection techniques

A preliminary pilot test was conducted in 15 subjects, where maximum heel support strength and transverse displacement of the COP were evaluated in the gait test. Using these data, the sample size was calculated as follows:

$$n = \frac{2(Za + Zb)^2 * S^2}{d^2}$$

Where,

Za= desired risk "z" value at a 95% interval confidence

Zb= desired risk "z" value at a 80% power

S= variance for the maximum heel support strength with a value of 100 (S), and a minimum value of difference between both groups of 8 Newton (d).

Procedure

Epidat 4 software was used to complete the estimated size "n" in each group (Table 1), the final value was increased by 10%. A simple randomization sequence was employed with a random number table. Numbers from 0 to 9 (sequence) were considered, where even numbers (0, 2, 4, 8) identified the experimental group (EG), and odd numbers (1, 3, 5, 7, 9), the control group (CG). This list was generated by a statistician in a simple Excel spreadsheet. Researchers were blinded to the designation of groups, and the instructors responsible

for implementing the intervention program received training to ensure strict dose control of physical activity (Figure 1).

Table 1. Physical characteristics of the participants before physical training (week 0).

Variables	Pretest EG (n=24) $\bar{x} \pm SD$	Pretest CG (n=23) $\bar{x} \pm SD$	Inter-sample comparison EG pretest vs. CG pretest
Age (years)	63.58±3.65	64.58±4.31	§
Body weight (kg)	63.80±8.01	60.75±9.35	§
Body mass index	27.40±3.43	25.67±3.59	§
Waist-hip ratio (cm)	0.90±0.06	0.88±0.07	§
Fat mass (%)	39.88±5.69	38.00±6.75	§
Muscle mass (%)	25.15±2.44	26.54±3.36	§

EG: Experimental group; CG: Control Group; ($\bar{x} \pm SD$): median and standard deviation; (§): No statistical significance.

Source: Own elaboration.

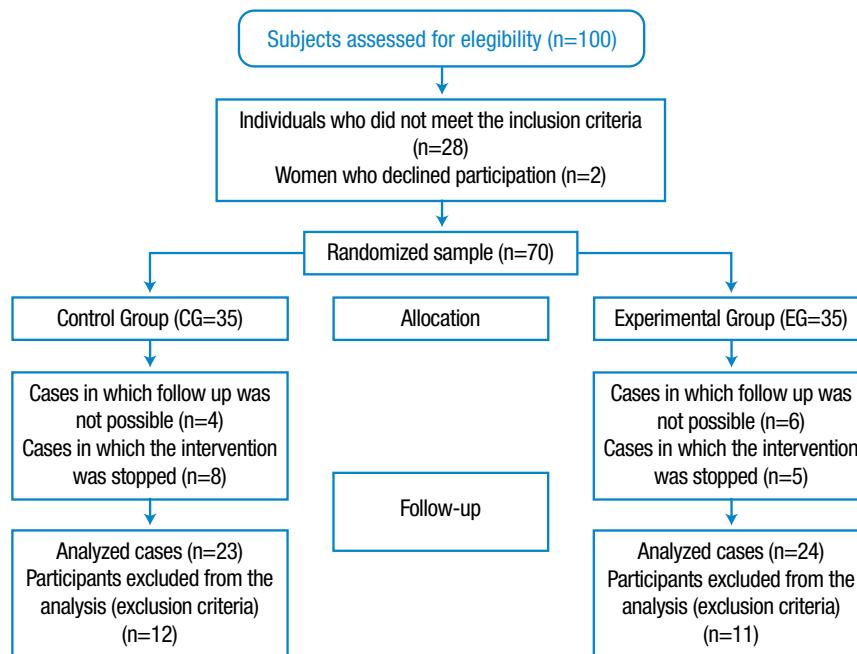


Figure 1. Selection process flow diagram

Source: Own elaboration based on the data obtained in the study and according to the Consolidated Standards of Reporting Trials. (26)

Intervention program

This proposal was evaluated and approved by double-blind peer reviewers, ensuring that the program, its methodology, the procedures to be carried out, the overloads to be used, and other related aspects, fulfilled the purpose of the research and guaranteed participants' integrity.

The program for the EG was designed based on impact and explosive exercises by means of routines consisting of performing series of jumps while using weighted vests with 10% to 30% overloads with respect to total body weight. Also, the EG intervention included actions per level that had a type A difficulty level (basic jumps with the support of both lower limbs and upper limb coordination on site or with displacement), type B difficulty level (limited support of one foot, with upper limb coordination, obstacles lower than 10 cm, with

or without displacement) and type C difficulty (limited support on one foot or both feet, limited upper limb coordination, turns and obstacles —combined or separately—, with and without displacement). On the other hand, the CG carried out their usual recreational activities under supervision. All the information described above coincides with a protocol proposed by our scientific team and already published. (28)

The undulating programming model was used to design the program. This way, if load intensity represented in the external load obtained through free weights was increased (30% overload with respect to each participant's total body weight), then the duration per exercise series decreased; on the contrary, if load intensity was reduced (10% overload with respect to each participant's total body weight), the duration per exercise series increased (Table 2). All exercises were performed with complete resting time.

Table 2. 32-week implementation model of the pool-based strength training program in a group of women aged 60 or over.

Strategy	Weeks	Frequency	Number of Exercises	Series	Repetitions	Total repetitions per week	Total repetitions per month
Impact and explosive movements (multiple jumps) with external loads (10% to 30% with respect to total body weight)	1-4	3	3	2	8	144	576
	5-8	3	3	3	8	216	864
	9-12	3	3	3	8	216	864
	13-16	3	3	2	8	144	576
	17-20	3	3	2	8	144	576
	21-24	3	3	3	8	216	864
	25-28	3	3	3	8	216	864
	29-32	3	3	2	8	144	576

Source: Own elaboration.

The program designed for the EG lasted 8 months and consisted of three sessions per week, with one hour per session. At the same time, the individuals in the CG participated in a water-based physical activity program consisting of non-systematized recreational activities (swimming and aerobics) and were asked not to make any significant changes in their physical activity routines during the intervention period. In addition, CG participants received monthly follow-up phone calls during the intervention period in order to check if any significant changes had been made. Both programs took place in a 1.50 m depth therapeutic pool with a constant temperature of 30°C.

Description of the procedures

All subjects were given sufficient information to completely understand evaluation tests, which were grouped into morphological variables (body mass index (BMI), total body weight, percentage of fat mass, and percentage of lean body mass) and functional variables (related to explosive strength: power, take-off time, flight time, and maximum height achieved; related to gait: maximum heel support strength, maximum double support strength, maximum toe take-off strength, and displacement of the COP). A warm-up and familiarization period with the protocol was performed 15 minutes before every test.

Both explosive strength and walking strength tests results were recorded three times for each movement on a P6000 digital force plate manufactured by BTS *Bioengineering*®, sampling at 1 kHz. *Smart Analyzer* software allowed recording the variables associated with the lower limb's explosive capacity and the functional indicators in the gait pattern. Each protocol is described below.

Body composition tests

A bioimpedance system (Omron Healthcare, HBF-510w, Inc. Bannockburn, IL, USA) was used according to the manufacturer's instruction manual:

- a) All personal data were entered before starting the test;
- b) All participants were asked to follow these instructions: first to stand with their knees and back straight and to look straight, then to raise their arms horizontally and to bend their elbow joints to form a 90° angle with respect to their bodies, and to hold the display unit in front of them;

c) Total body weight, body fat percentage, fat-free body mass percentage, and BMI measurements were obtained.

Explosive strength tests

A jump protocol was used where the range of articular mobility was varied. (29) Explosive strength was measured based on each subject's response to a vertical maximum jump, a squat jump (SJ: the starting position is from a position of flexion of the knee joint at 90°, with hands on the hips, and jumping vertically), a countermovement jump (CMJ: the starting position is standing, with full extension of the knees, the person flexes and reaches 90° and immediately jumps vertically), and a countermovement jump with arm swing (CMJas: similar to the previous jump but using the upper limbs to reach the highest possible height).

Gait test

According to the recommendations of the manufacturer of the BTS® recording device and of the European Working Group on Sarcopenia in Older People (EWGSOP) (19,20), each participant was asked to walk a 6-meter distance three times at normal speed, by leaving and entering the recording space every time. This made possible obtaining information about maximum heel support strength, maximum double support strength, maximum toe take-off strength, COM, and COP by means of 3D Digivec software and Smart Analyzer software.

Statistical analysis

Statistical analysis was made using the SPSS software, version 22, where means, standard deviations and correlation coefficients were calculated by using standardized statistical methods. Considering the sample size, the Shapiro-Wilk test, with a graphical distribution using a normality curve, and the homoscedasticity test were applied. Differentiation levels of 5% were established with a 95% confidence interval and $p < 0.05$ values were statistically analyzed.

After applying and confirming the established criteria for suggesting a statistical model and after observing variables values that did not meet normality parameters, non-parametric Mann-Whitney U and Wilcoxon tests were applied to establish inter and intra-sample differences. Likewise, a relative risk (RR) test was conducted for estimating the probability of presence-absence of adaptations between groups.

Results

Body composition

After the EG completed the program, no significant differences between EG and CG were found ($p<0.05$ and 0.001). Weight (kg) decreased by 2% in the EG and by 1% in the CG ($p=0.31$), (Table 3).

Table 3. Morphological and explosive strength changes between the EG and the CG before and after the 32-week pool-based strength-training program.

Variables	Pre-test EG (n=24)	Post-test EG (n=24)	Pre-test CG (n=23)	Post-test CG (n=23)	EG Intra-sample comparison	CG Intra-sample comparison	EG vs. CG Inter-sample comparison
	$\bar{x} \pm SD$	$\bar{x} \pm SD$	$\bar{x} \pm SD$	$\bar{x} \pm SD$	Pre-test vs. Post-test	Pre-test vs. Post-test	Pre-test vs. Post-test
Body weight (Kg)	63.80 \pm 8.01	62.62 \pm 8.56	60.75 \pm 9.35	60.25 \pm 7.92	§	§	§
Body mass index	27.40 \pm 3.43	26.96 \pm 3.52	25.67 \pm 3.59	25.14 \pm 3.09	*	§	**
Waist-hip ratio (cm)	0.90 \pm 0.06	0.92 \pm 0.15	0.88 \pm 0.07	0.90 \pm 0.15	*	§	§
Fat mass (%)	39.88 \pm 5.69	40.14 \pm 5.36	38.00 \pm 6.75	36.88 \pm 5.53	*	§	**
Muscle mass (%)	25.15 \pm 2.44	24.89 \pm 2.14	26.54 \pm 3.36	25.78 \pm 2.28	§	§	§
Maximum impulse strength (N)-SJ	481.539 \pm 82.76	489.218 \pm 84.97	497.13 \pm 87.53	500.78 \pm 91.12	§	§	§
Maximum support strength (N)-SJ	1427.56 \pm 544.48	1187.28 \pm 324.07	1438.32 \pm 527.88	1308.37 \pm 489.13	§	§	§
Flight time (s)-SJ	0.30 \pm 0.03	0.34 \pm 0.03	0.31 \pm 0.12	0.33 \pm 0.05	§	§	§
Jump height (cm)-SJ	0.11 \pm 0.02	0.15 \pm 0.02	0.9 \pm 0.02	0.12 \pm 0.03	*	§	*
Power (W)-SJ	218.258 \pm 36.82	265.843 \pm 24.40	217.24 \pm 36.51	232.44 \pm 26.23	**	*	*
Maximum impulse strength (N)-CMJ	538.12 \pm 101.08	529.54 \pm 98.67	591.26 \pm 122.01	561.13 \pm 137.46	§	§	§
Maximum support strength (N)-CMJ	1542.47 \pm 557.89	1114.67 \pm 295.14	1513.46 \pm 621.11	1466.09 \pm 571.16	**	§	*
Flight time (s)-CMJ	0.31 \pm 0.04	0.35 \pm 0.03	0.29 \pm 0.03	0.31 \pm 0.12	§	§	§
Jump height (cm)-CMJ	0.12 \pm 0.02	0.15 \pm 0.03	0.10 \pm 0.04	0.12 \pm 0.03	*	§	*
Power (W)-CMJ	226.83 \pm 37.86	274.131 \pm 25.26	225.956 \pm 35.67	242.239 \pm 37.61	*	§	*
Maximum impulse strength (N)-CMJas	556.64 \pm 95.41	525.10 \pm 114.63	547.86 \pm 94.21	539.53 \pm 98.46	§	§	§
Maximum support strength (N)-CMJas	1449.07 \pm 438.95	1127.03 \pm 350.42	1436.93 \pm 591.13	1239.94 \pm 459.01	*	*	*
Flight time (s)-CMJas	0.33 \pm 0.04	0.37 \pm 0.03	0.29 \pm 0.03	0.32 \pm 0.05	*	§	*
Jump height (cm)-CMJas	0.12 \pm 0.03	0.17 \pm 0.03	0.11 \pm 0.01	0.13 \pm 0.03	**	§	*
Power (W)-CMJas	243.269 \pm 42.39	289.466 \pm 26.05	235.391 \pm 37.31	251.751 \pm 38.42	**	§	*

EG: experimental group; CG: control group; ($\bar{x} \pm SD$): median and standard deviation; (§): No significance; (*): $p<0.05$ significance; (**): $p<0.001$ significance.

Source: Own elaboration.

Explosive strength tests

Changes in lower limb explosive strength were analyzed through five performance indicators in relation to the execution of SJ, CMJ and CMJas, namely, maximum impulse strength, maximum support strength, flight time, jump height, and power (Table 3).

Maximum impulse strength in SJ, CMJ and CMJas performance tests were not significantly different between the EG and the CG. No significant changes ($p<0.05$ and 0.001) were found in the EG values obtained in the SJ ($1.5 \pm 2.67\%$), CMJ ($-1.59 \pm 2.38\%$) and CMJas ($-5.66 \pm 2.14\%$) performance tests, nor in the CG, with values

BMI (kg/m^2) decreased by 1.6% in the EG and by 2% in the CG ($p=0.065$), waist-to-hip ratio (WHR)(cm) increased in the same proportion in both groups ($p=0.244$), and muscle mass decreased by 1% in the EG and by 3% in the CG, although differences were not statistically significant ($p=0.200$). Finally, fat mass increased by 1% in the EG and decreased by 3% in the CG ($p=0.042$) (Table 3).

of ($0.72 \pm 3.93\%$), ($5.36 \pm 2.23\%$) and ($1.54 \pm 3.31\%$), respectively. However, it is worth nothing that there was a trend towards improvement in the EG in comparison with the CG.

The second indicator, that is, maximum support strength, was significantly different between both groups. Significant decreases were found ($p<0.05$ and 0.001) in the EG in CMJ ($-27.73 \pm 7.09\%$) and CMJas ($-22.22 \pm 5.16\%$) performance tests, but no significant changes were observed in the SJ test. On the other hand, significant changes in the CG ($p<0.05$ and 0.001) were observed in relation to SJ ($-9.93 \pm 4.92\%$) and CMJas ($-15.88 \pm 4.7\%$) performance tests, but there were no significant changes in the CMJ ($-3.23 \pm 1.74\%$) test.

Flight time significantly increased in the CMJas tests in both groups, but no significant changes were reported in the SJ and CMJ tests. In the EG, positive and significant results ($p<0.05$ and 0.001) in the SJ ($13.33\pm0.01\%$), CMJ ($12.90\pm5.01\%$) and CMJas ($12.12\pm5.01\%$) performance tests were observed, as well as changes in the CG ($p<0.05$ and 0.001) regarding the SJ ($6.06\pm3.31\%$), CMJ ($6.45\pm1.7\%$) and CMJas ($9.37\pm1.3\%$) tests.

Regarding jump height, the fourth indicator, a higher increase was observed in all tests in the EG. Positive and significant values were observed ($p<0.05$ and 0.001) in the EG in the SJ ($36.36\pm0.02\%$), CMJ ($25.00\pm0.12\%$) and CMJas ($21.42\pm0.01\%$) tests, as well as changes in the CG ($p<0.05$ and 0.001) in the SJ ($25.33\pm4.21\%$), CMJ ($16.16\pm3.33\%$) and CMJas ($15.34\pm6.66\%$) tests.

Finally, power indicator values in all tests were in agreement with the behavior of the other indicators. This indicator was further increased in the EG, since a significant increase in this group was observed ($p<0.05$ and 0.001) in SJ ($21.80\pm3.37\%$), CMJ ($20.83\pm3.32\%$) and CMJas ($18.99\pm8.9\%$) tests, while in the CG percentage values, increase behavior was inferior: SJ ($6.53\pm3.91\%$), CMJ ($6.72\pm5.18\%$) and CMJas ($6.49\pm2.88\%$).

Table 4. Gait changes between groups before and after the 32-week pool-based strength-training program

Variables	Low limb tested	PRE-TEST EG (n=24)	Post-test EG (n=24)	Pre-test CG (n=23)	Post-test CG (n=23)	EG intra-sample comparison	CG intra sample comparison	EG vs. CG inter-sample comparison
		$\bar{x}\pm SD$	$\bar{x}\pm SD$	$\bar{x}\pm SD$	$\bar{x}\pm SD$	Pre-test vs. Post-test	Pre-test vs. Post-test	Post-test vs. Post-test
SmxHS (N)	LF	612.68 \pm 93.34	563.51 \pm 105.48	630.21 \pm 98.20	566.81 \pm 128.66	**	**	*
SmxDHS (N)	LF	473.41 \pm 67.62	475.86 \pm 94.19	481.86 \pm 88.22	481.01 \pm 87.91	§	§	*
SmxTT (N)	LF	621.67 \pm 94.18	569.93 \pm 103.94	615.44 \pm 93.35	572.02 \pm 89.44	**	§	§
SmxHS (N)	RF	584.52 \pm 93.75	573.67 \pm 96.27	584.57 \pm 133.444	605.48 \pm 104.84	§	§	§
SmxDHS (N)	RF	465.30 \pm 77.8	485.46 \pm 77.22	433.48 \pm 107.74	504.85 \pm 74.77	§	§	§
SmxTT (N)	RF	598.73 \pm 86.85	580.53 \pm 101.18	593.94 \pm 138.61	610.26 \pm 93.03	§	§	§

EG: Experimental group; CG: Control group; SmxHS: maximum heel-support strength; SmxDHS: maximum double heel-support strength; SmxTT: maximum toe take-off strength; LF: left foot; RF: Right foot. $\bar{x}\pm SD$: median and standard deviation; (§): No significance; (*): $p<0.05$ significance; (**): $p<0.001$ significance; (N): Newton.

Source: Own elaboration based on the data obtained in the study.

In addition, COP transversal displacement (COPt) and COP longitudinal displacement (COPi) indicators experienced a significant decrease ($p<0.05$ and 0.001) in the EG ($-106.32\pm42.74\%$ and $-47.93\pm43.36\%$, respectively), while in the CG, COPt values tended to increase significantly ($17.65\pm42.74\%$), although a slight reduction in COPi values was observed. A relative risk was estimated for these data [(RR=2.52; 95% confidence interval (Li=1.29 and Ls=3.06)], indicating that exposure to the physical activity program represented a 2.52-fold increase in relation to the possibility of reducing COPi and COPt records; in other words, the model used here favored the decrease of COP values in the displacement (Figure 2).

Discussion

The objective of this study was to establish the effects of an explosive movements and impact exercises water training program on gait parameters of women aged 60 years and above. The results obtained here reveal significant changes between both groups in terms of body composition (BMI and percentage of fat mass), and in relation to indicators of lower limb muscle strength and gait.

The first component analyzed was body composition, where significant changes were observed between the groups (EG and

Gait test

The biomechanical efficiency of the gait pattern was analyzed using three right and left foot performance indicators: maximum heel-support strength (SmxHS), maximum double heel-support strength (SmxDHS), and maximum toe take-off strength (SmxTT).

Values obtained for SmxHS and SmxTT indicators were significantly different between the EG and the CG, and with a tendency to compensate tread between right and left side recordings. Left foot SmxHS and SmxTT records changed significantly ($p<0.05$ and 0.001) in the EG: ($-8.02\pm5.01\%$) and ($-8.32\pm6.23\%$), respectively. Other indicator values followed a trend towards diminishing and compensating the forces exerted in the gait cycle phases, which improved tread efficiency.

On the other hand, SmxHS, SmxDHS and SmxTT values in the CG followed an increase and decompensation pattern between forces exerted by both sides in each phase of the gait cycle and the tread. An example of this pattern is the significant change ($p<0.05$ and 0.001) of the SmxDHS indicator of the left side, in which an increase ($16.46\pm9.1\%$) was observed. All indicators values and their trends are depicted in Table 4.

CG) for the BMI variable, which presented a decrease ($p=0.05$), while the percentage of fat mass increased in the EG ($p=0.042$). This could be explained by the objective of the physical activity program implemented and the body bioimpedance assessment method that was used. Other elements that could explain these results are related to diet, body fluids, hydration status, and environmental and body temperature, which affect the control of biases for research. (30)

In this sense, similar results have been reported for morphological variables after 12 weeks of aerobic training in water accompanied by music, where significant changes in BMI and body mass were observed ($p<0.001$) (31). On the other hand, Ochoa-Martínez *et al.* (32) reported they did not find significant changes in body fat (kg) and muscle mass in older adult women after 12 weeks of hydrogymnastics.

Although there were no significant changes in muscle mass, it is worth noting that a decrease was found in a smaller proportion for the EG (the loss of muscle mass in the EG and CG was 1% and 3%, respectively). These data are in agreement with several studies (33,34) describing that movements at maximum intensity, in short periods of time with or without a combination of joint impact, delay the loss of muscle mass compared to a recreational physical activity program when applied to adults over 60 years of age.

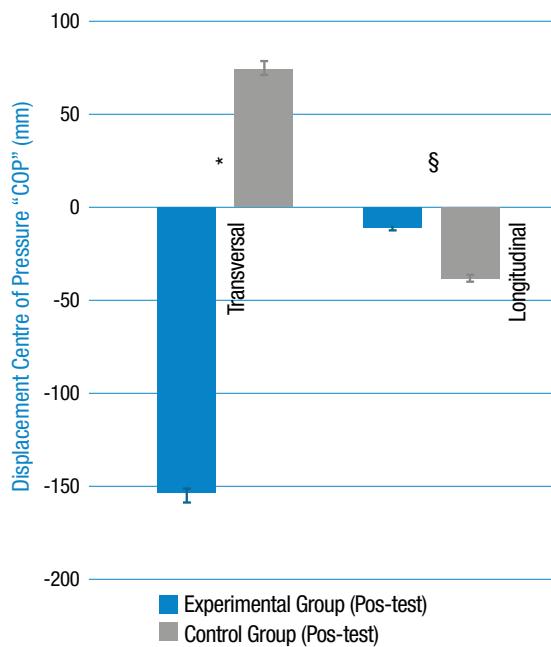


Figure 2. Center of pressure changes between EG and CG before and after the 32-week pool-based strength training program
 EG: Experimental group; CG: control group; n= sample; $\bar{x} \pm SD$: median and standard deviation; (\$): No significance; (*) $p<0.05$ significance.
 Source: Own elaboration based on the data obtained in the study.

On the other hand, regarding the assessment of explosive strength of lower limbs, several performance indicators were analyzed during the SJ, CMJ and CMJas tests. These records yielded highly significant changes for the EG and the CG in the CMJ and CMJas tests for maximum impulse force ($p \leq 0.001$), which means that EG participants performed less impulse force compared to CG participants.

Also, concerning the flight time, jump height and power indicators, the increased values observed in the CMJas test indicate that the speed of execution of the movement was higher in the EG, which is similar to what Pereira *et al.* (16) reported on the jumping capacity in water of postmenopausal women. In addition, some values obtained in height (cm) and power (W) are higher in relation to programs that only use one of the two movements (explosive or impact) on land, as described in other studies. (35,36)

In this regard, some studies (37-38) have found that increasing muscle power favors the stimulation of the neuromuscular system and enhances the functionality of older adults, which allows a better performance in the activities of daily life. One of the mechanisms that explains these results is related to the stretch-shortening cycle that is associated with greater efficiency of the elastic component that favors damping. (32)

It is worth noting that some clinical trials (39) where physical activity programs were implemented in water environments, have described gains in muscle strength, body composition and bone mineral density, factors that improve fitness in older adults.

With respect to the last component, gait assessment showed statistically significant changes after the intervention in the supportive phases between the EG and the CG, for both feet. Although few studies have assessed these variables in gait performance, it has been shown that there are no significant changes between groups as reported by Zamanian *et al.* (40) In addition, other studies have not found significant differences between young and old subjects when walking in water; nevertheless, the difference between support in water and on land is considered to be between 2% and 6%, respectively.

However, significant differences were found in the displacement of the COP during gait, especially in transverse displacement ($p=0.033$), which had a greater decrease in the EG. Therefore, COP can be considered as a representative variable in gait analysis that influences older adults' functionality, as shown by Cadore *et al.* (6), who reported an improvement in gait ability after a training period, as the average ability increased from 4% to 50%. Furthermore, other studies (41-45) have reported that in this population the risk of falls drops by up to 50% as there is less displacement of the COP during gait.

Some limitations of the present study include the impact of sample loss for each group and the inclusion of a more rigorous caloric intake control procedure (quality vs. quantity). In this regard, reviewing these considerations and combining the model studied here with programs that maintain and increase muscle mass is highly suggested since such model, theoretically, could enhance the results achieved separately.

Conclusion

The aquatic training program presented here produced an increase in muscle strength and muscle power, thus gait parameters were improved. Taking this into account, an improved availability of similar physical activity programs for older adults should be considered, since their participation in said programs could contribute to the improvement of their functional capacity, and, thus, their quality of life.

Conflicts of interest

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References

1. Nikander R, Sievänen H, Heinonen A, Daly RM, Uusi-Rasi K, Kannus P. Targeted exercise against osteoporosis: A systematic review and meta-analysis for optimising bone strength throughout life. *BMC Medicine*. 2010;8(1):47. <http://doi.org/b366f2>.
2. Kanis JA, Odén A, McCloskey EV, Johansson H, Wahl DA, Cooper C. A systematic review of hip fracture incidence and probability of fracture worldwide. *Osteoporos Int*. 2012;23(9): 2239-56. <http://doi.org/f3ts56>.
3. Hobbs N, Godfrey A, Lara J, Errington L, Meyer TD, Rochester L, *et al.* Are behavioral interventions effective in increasing physical activity at 12 to 36 months in adults aged 55 to 70 years? A systematic review and meta-analysis. *BMC Medicine*. 2013;11(1):75. <http://doi.org/gb33n6>.
4. Curtis EM, Moon RJ, Harvey NC, Cooper C. Reprint of: The impact of fragility fracture and approaches to osteoporosis risk assessment worldwide. *Int J Orthop Trauma Nurs*. 2017;26:7-17. <http://doi.org/c8hq>.
5. Muir JM, Ye C, Bhandari M, Adachi JD, Thabane L. The effect of regular physical activity on bone mineral density in post-menopausal women aged 75 and over: a retrospective analysis from the Canadian multicentre osteoporosis study. *BMC Musculoskelet Disord*. 2013;14(1):253. <http://doi.org/gbdkpq>.
6. Cadore EL, Rodríguez-Mañas L, Sinclair A, Izquierdo M. Effects of different exercise interventions on risk of falls, gait ability, and balance in physically frail older adults: a systematic review. *Rejuvenation Res*. 2013;16(2):105-14. <http://doi.org/gfvw87>.

7. **Kim HK, Susuki T, Saito K, Yoshida H, Kobayashi H, Kato H, et al.** Effects of exercise and amino acid supplementation on body composition and physical function in community-dwelling elderly Japanese sarcopenic women: a randomized controlled trial. *J Am Geriatr Soc.* 2012;60(1):16-23. <http://doi.org/b877qf>.
8. **Freiberger E, Häberle L, Spirduso WW, Zijlstra GA.** Long-term effects of three multicomponent exercise interventions on physical performance and fall-related psychological outcomes in community-dwelling older adults: a randomized controlled trial. *J Am Geriatr Soc.* 2012;60(3):437-46. <http://doi.org/cnpm>.
9. **Lustosa LP, Silva JP, Coelho FM, Pereira DS, Paretoni AN, Pereira LS.** Efeito de um programa de resistência muscular na capacidade funcional e na força muscular dos extensores do joelho em idosas pré-frágeis da comunidade: ensaio clínico aleatorizado do tipo crossover. *Rev Bras Fisioter.* 2011;15(4):318-24. <http://doi.org/d6p7bx>.
10. **Serra-Rexach JA, Bustamante-Ara N, Hierro-Villarán M, González-Gil P, Sanz-Ibáñez MJ, Blanco-Sanz N, et al.** Short-term, light- to moderate-intensity exercise training improves leg muscle strength in the oldest old: a randomized controlled trial. *J Am Geriatr Soc.* 2011;59(4):594-602. <http://doi.org/d9w266>.
11. **Kenny AM, Boxer RS, Kleppinger A, Brindisi J, Feinn R, Burleson JA.** Dehydroepiandrosterone combined with exercise improves muscle strength and physical function in frail older women. *J Am Geriatr Soc.* 2010;58(9):1707-14. <http://doi.org/dw73pk>.
12. **Taylor D, Hale L, Schluter P, Waters DL, Binns EE, McCracken H, et al.** Effectiveness of Tai Chi as a community-based falls prevention intervention: A randomized controlled trial. *J Am Geriatr Soc.* 2012;60(5):841-8. <http://doi.org/cnps>.
13. **Hortobágyi T, Tunnel D, Moody J, Beam S, DeVita P.** Low- or high-intensity strength training partially restores impaired quadriceps force accuracy and steadiness in aged adults. *J Gerontol A Biol Sci Med Sci.* 2001;56(1):B38-47. <http://doi.org/bxfzkt>.
14. **Korpelainen R, Keinänen-Kiukaanniemi S, Heikkinen J, Väänänen K, Korpelainen J.** Effect of exercise on extraskeletal risk factors for hip fractures in elderly women with low BMD: a population-based randomized controlled trial. *J Bone Miner Res.* 2006;21(5):772-9. <http://doi.org/d3dqxb>.
15. **McKinnon, NB, Connelly DM, Rice CL, Hunter SW & Doherty, TJ.** Neuromuscular contributions to the age-related reduction in muscle power: mechanisms and potential role of high velocity power training. *Ageing Res Rev.* 2017;35:147-154. <http://doi.org/gf5h59>.
16. **Pereira A, Izquierdo M, Silva AJ, Costa AM, Bastos E, González-Badillo JJ, et al.** Effects of high-speed power training on functional capacity and muscle performance in older women. *Exp Gerontol.* 2012;47(3):250-5. <http://doi.org/fx27bv>.
17. **Katsura Y, Yoshikawa T, Ueda SY, Usui T, Sotobayashi D, Nakao H, et al.** Effects of aquatic exercise training using water-resistance equipment in elderly. *Eur J Appl Physiol.* 2010;108(5):957-64. <http://doi.org/c7zrfw>.
18. **Hale LA, Waters D, Herbison P.** A randomized controlled trial to investigate the effects of water-based exercise to improve falls risk and physical function in older adults with lower-extremity osteoarthritis. *Arch Phys Med Rehabil.* 2012;93(1):27-34. <http://doi.org/fw2vpt>.
19. **Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, et al.** Sarcopenia: revised European consensus on definition and diagnosis. *Age Ageing.* 2019;48(1):16-31. <http://doi.org/gff7f8>.
20. **Van Iersel MB, Benraad CE, Rikkert MG.** Validity and reliability of quantitative gait analysis in geriatric patients with and without dementia. *J Am Geriatr Soc.* 2007;55(4):632-4. <http://doi.org/dgq3gs>.
21. **Kemoun G, Thoumie P, Boisson D, Guieu JD.** Ankle dorsiflexion delay can predict falls in the elderly. *J Rehabil Med.* 2002;34(6):278-83. <http://doi.org/d5h67s>.
22. **Pitzer-Neto VE, Rombaldi AJ, de Oliveira-Saes M, Vinholes-Siqueira F.** Physical activity and gait kinematics in the elderly. *Rev Bras Ativ Fís Saúde.* 2015;20(3):243. <http://doi.org/c8jz>.
23. **Wang E, Nyberg SK, Hoff J, Zhao J, Leivseth G, Tørhaug T, et al.** Impact of maximal strength training on work efficiency and muscle fiber type in the elderly: Implications for physical function and fall prevention. *Exp Gerontol.* 2017;91:64-71. <http://doi.org/f95wsp>.
24. **Pirker W, Katzenschlager R.** Gait disorders in adults and the elderly: a clinical guide. *Wien Klin Wochenschr.* 2017;129(3-4):81-95. <http://doi.org/f9sgwd>.
25. **McHugh J.** Guidelines: CONSORT statement extended for pilot trials. *Nat Rev Rheumatol.* 2016;12(12):692. <http://doi.org/c8j3>.
26. World Medical Association (WMA). WMA Declaration of Helsinki. Ethical principles for medical research involving human subjects. Fortaleza: 64th WMA General Assembly; 2013.
27. Colombia. Ministerio de Salud. Resolución 8430 de 1993 (octubre 4): Por la cual se establecen las normas científicas, técnicas y administrativas para la investigación en salud. Bogotá D.C.: octubre 4 de 1993.
28. **Ramírez-Villada JF, Leon-Ariza HH, Argüello-Gutiérrez YP, Porrás-Ramírez KA.** Efecto de los movimientos explosivos y de impacto aplicados en piscina sobre la composición corporal, la fuerza y la densidad mineral ósea de mujeres mayores de 60 años. *Rev Esp Geriatr Gerontol.* 2016;51(2):68-74. <http://doi.org/c8j8>.
29. **Bosco C, Luhtanen P, Komi PV.** A simple method for measurement of mechanical power in jumping. *Eur J Appl Physiol Occup Physiol.* 1983;50(2): 273-82. <http://doi.org/cbfvtf>.
30. **Sánchez-Jaeger A, Barón MA.** Uso de la bioimpedancia eléctrica para la estimación de la composición corporal en niños y adolescentes. *Anales Venezolanos de Nutrición.* 2009;22(2):105-10.
31. **Kasprzak Z, Pilaczyńska-Szczęśniak L.** Effects of regular physical exercises in the water on the metabolic profile of women with abdominal obesity. *J Hum Kinet.* 2014;41:71-9. <http://doi.org/c8kc>.
32. **Ochoa-Martínez PY, Hall-López JA, Alarcón-Meza EI, Piña-Díaz D, Estélio-Henrique MD.** Effect of 3-Month Water-Exercise Program on Body Composition in Elderly Women. *Int J. Morphol.* 2014;32(4):1248-53. <http://doi.org/c8kd>.
33. **Avelar-Núbia CP, Bastone-Alessandra C, Alcântara-Marcus A, Gomes-Wellington F.** Effectiveness of aquatic and non-aquatic lower limb muscle endurance training in the static and dynamic balance of elderly people. *Rev. bras. fisioter.* 2010;14(3):229-36. <http://doi.org/dd49q5>.
34. **Carrasco-Poyatos M, Vaquero-Abellán M.** Mejora de la capacidad de salto en mujeres postmenopáusicas con moderado riesgo de fractura de cadera tras dos años de ejercicio en el medio acuático. *Retos: Nuevas tendencias en Educación Física, Deporte y Recreación.* 2010;17:25-9.
35. **Piirainen JM, Linnamo V, Sippola N, Avela J.** Neuromuscular function during drop jumps in young and elderly males. *J Electromyogr kinesiol.* 2012;22(6):852-8. <http://doi.org/c8kf>.
36. **Ramírez-Campillo R, Castillo A, de la Fuente CI, Campos-Jara C, Andrade DC, Alvarez C, et al.** High-speed resistance training is more effective than low-speed resistance training to increase functional capacity and muscle performance in older women. *Expl Gerontol.* 2014;58:51-7. <http://doi.org/c8kh>.
37. **Casas-Herrero A, Cadore EL, Martínez-Velilla N, Izquierdo-Redin M.** El ejercicio físico en el anciano frágil: una actualización. *Rev Esp Geriatr Gerontol.* 2015;50(2):74-81. <http://doi.org/f25tv4>.
38. **Izquierdo M, Ibáñez J, Antón M, Cebollero-Ribas P, Cadore EL, Casas-Herrero A, et al.** Ejercicio físico es salud. Prevención y tratamiento de enfermedades mediante la prescripción de ejercicio físico. 2nd ed. Execycle SL, BH Group; 2014.
39. **Wang TJ, Belza B, Thompson F, Whitney JD, Bennett K.** Effects of aquatic exercise on flexibility, strength and aerobic fitness in adults

with osteoarthritis of the hip or knee. *J Adv Nurs.* 2007;57(2):141-52. <http://doi.org/d89rbs>.

40. Zamanian F, Sedighi Z, Satar S, Leila Z. The Role of Aquatic Exercise on Strength of Quadriceps Muscle and Falling Risk in Elderly People. *Res J Sport Sci.* 2013;1(1):26-34.

41. Ramírez-Villada JF, León-Ariza HH, Sánchez-Jiménez A, Sepúlveda CM. Alterations in body composition, capillary glucose and functionality during explosive strength training in older women. *Int J Disabil Hum Dev.* 2016;15(3):251-9. <http://doi.org/c8kj>.

42. Colado JC, Garcia-Masso X, Rogers ME, Tella V, Benavent J, Dantas EH. Effects of aquatic and dry land resistance training devices on body composition and physical capacity in postmenopausal women. *J Hum Kinet.* 2012;32:185-95. <http://doi.org/gbcpv4>.

43. Bovi G, Rabuffetti M, Mazzoleni P, Ferrarin M. A multiple-task gait analysis approach: kinematic, kinetic and EMG reference data for healthy young and adult subjects. *Gait Posture.* 2011;33(1):6-13. <http://doi.org/cxmmx5>.

44. Lim HS, Yoo S. The Influence of Short-term Aquatic Training on Obstacle Crossing in Gait by the Elderly. *J Phys Ther Sci.* 2014;26(8):1219-22. <http://doi.org/c8kk>.

45. Pau M, Leban B, Collu G, Migliaccio GM. Effect of light and vigorous physical activity on balance and gait of older adults. *Arch Gerontol Geriatr.* 2014;59(3):568-73. <http://doi.org/c8km>.