 DOI: http://dx.doi.org/10.1590/S1980-6574201700020011

Original article (short paper)

Effects of two programmes of combined Land-Based and Water-Based exercise on the cognitive function and fitness levels of healthy older adults

José Maria Cancela Carral
HealthyFit Research Group, Galicia Sur Health Research Institute (IIS Galicia Sur). SERGAS-UVIGO. Faculty of Education and Sport Sciences. University of Vigo, Spain.

David Malvido Currás
Faculty of Education and Sport Sciences. University of Vigo, Spain.

Carlos Ayán Pérez
HealthyFit Research Group, Galicia Sur Health Research Institute (IIS Galicia Sur). SERGAS-UVIGO. Faculty of Education and Sport Sciences. University of Vigo, Spain.

Maria Helena Vila Suárez
HealthyFit Research Group, Galicia Sur Health Research Institute (IIS Galicia Sur). SERGAS-UVIGO. Faculty of Education and Sport Sciences. University of Vigo, Spain.

Abstract — Very little is known about the influence training programmes that combine land-based and water-based exercises might have on the cognitive function of healthy older people. **Aim**: to analyze the combined effect of two physical exercise programs (water-based and land-based) on fitness level and cognitive function. **Method:** 15 senior citizens carried out a water and land-based exercise program (EF group), while 22 senior citizens followed the same program with the addition of cognitive training performed in water (EC group). The effects of both programs were assessed by means of the Symbol Digit Modalities, the Two-minute step and the Timed-up-and-go tests. **Results:** The data obtained showed that both programs had significant effects on the participants' fitness level and cognitive function, although only those in the EC group showed a significantly higher improvement. **Conclusion:** The combination of water-based and land-based exercise may lead to improvements in cognitive functions and fitness levels in healthy older adults. The inclusion of cognitive exercises performed in water seems to maximise these effects.

Keywords: cognitive enhancement. quality of life. learning and memory. physical exercise in water. physical activity. exercise aerobic.

Introduction

Exercising regularly is a strategy of proved efficacy to attenuate the advance of cognitive aging in healthy older adults. In fact, scientific evidence has brought to light that this effect is present both in "classic" training programmes (aerobic exercise and muscular strength-resistance)[1] and in those deemed "alternative" (yoga, tai-chi, or "exergame" interactive exercises, among others)[2,3]. However, there are several questions that still remain open to debate, and about which scientific evidence needs to be furthered. For instance, swimming pool-based exercise stands as one of the most appealing options for the elderly. Nevertheless, very few research studies have endeavoured to pinpoint their effects on the cognitive functions of this population in particular[4]. In addition, very little is known about the influence training programmes that combine land-based and water-based exercises might have on the cognitive function of healthy older people[3]. Finally, it has been suggested that the benefits of physical exercise for cognition might be greatly increased if this were part of a multimodal programme where physical exercise is combined with cognitive training[5]. In spite of this, studies comparing the efficacy of these types of programmes against other alternatives seem to be an urgent necessity in the field. Under these circumstances the present pilot study pursues a double aim: on the one hand, to identify the effects of a combination of land-based and water-based exercise programmes on the cognitive functions and fitness levels of healthy older people; on the other hand, to compare the dimension of said effects relative to the inclusion of cognitive training as part of one of the programmes offered.

Methods

Participants

Participants in this study were recruited through a programme aimed in promoting physical exercise among older adults, which was sponsored by the local council where the study was implemented. Individuals who met the following criteria were included: (a) being 65 or older; (b) obtaining a total score above 24 points in the Spanish-adapted version of the Mini-Mental

State Examination[6]; and c) being able to walk independently. All those who presented health problems that advised against the practice of physical exercise or in any way prevented the appropriate performance of any one of the assessments in the study, as well as those who were taking part in any other physical exercise or cognitive stimulation programme, were excluded. Prior to the implementation of the study, the authors were granted approval from the Local Ethics Committee, and the informed consent of all participants was requested.

Assessment

Cognitive function: The effects of the programme on the cognitive function of participants were measured by Symbol Digit Modalities Test (SDMT), a neurological test structured around the assessment of certain neurocognitive functions, mainly work memory, information processing speed, sustained, focalised and selective attention, visual-spatial function and constructive praxias. A written version of SDMT was administered in this study, making use of the standard dimensions plate for the Spanish language[7]. The objective of this test is to identify nine symbols with a variety of geometric shapes, which, in turn, correspond to numbers 1 to 9. Then, a series of blank spaces must be filled using the appropriate number under each geometric shape. After a test period when the subject is helped to fill in the first ten blanks, he or she is then timed for 90 seconds and asked to fill in as many blanks as possible. The highest mark is 110 points.

Physical condition: The effects of the programme on the aerobic capacity of the group of participants were assessed using the 2-minute step test (2MST)[8]. To carry out this test, the subject, in standing position, must face a wall where a line with a length equivalent to the distance between the subject's iliac crest and kneecap has been drawn. Afterwards, the subject is required to lift his or her knees alternately, until they reach the height of the line, for two minutes. After two attempts, the highest number of successful knee lifts is registered. The Timed-up-and-Go test (TUG)[9] was used to evaluate the effects of the programme on the participants' dynamic balance. In this test, the subject starts out sitting down on a chair, back against the backrest, arms crossed over the chest. After the signal, the subject must get up and go round a cone placed 2.44 metres from the chair, walk back and sit down again. The distance must be covered as quickly as possible, but always walking. Two attempts are allowed. The best mark of the two is registered.

All assessments were conducted one week before the start of the intervention and one week after its completion. Two experts in physical activity and gerontology applied these assessments.

Intervention

Participants were distributed in two groups: physical exercise without cognitive training (EF group) and physical exercise with cognitive training (EC group), according to their time availability and preferences after being informed of the programme timetables. Both groups completed one water-based training session (60 minutes) and another land-based session (60 minutes) once per week, in non-consecutive days, for a period of three months. The land-based session was held in a sports pavilion and featured callisthenic exercises aimed at improving aerobic capacity, balance, coordination and strength-resistance, and it was the same for both groups. In the case of EF group, the water-based session focused on developing strength-resistance, balance, coordination and aerobic capacity. Subjects of EC group combined several of these exercises with other tasks intended to stimulate cognitive functions through movement. For the purposes of this study, a series of exercises originally used in BrainGym® therapy[10] were adapted to water-based sessions (Table 1). These sessions were held in a 20 × 6 m swimming pool, 110 cm deep. Water temperature was 30 °C. A graduate in Physical Activity and Sport with previous experience in physical activity and the elderly supervised both exercise programmes.

Statistical analysis

The results were processed using a descriptive and inferential statistical analysis. To this end, Statistical Package for the Social Sciences v. 20.0 (SPSS) was employed. The data are presented as average ± standard deviation (SD). Sample normality was checked using the Shapiro-Wilk test ($p > 0.05$). Student's unpaired t-test was applied with the purpose of analysing whether the EF and EC groups where homogeneous relative to the programme they were allocated. The intra-group effect of each training program taking into account the two measurement moments (pre vs post) was determined by means of Student's paired t-test. Variance analysis (ANOVA 2 x 2; Moment x Group) with Bonferroni post hoc test was also used to try to grasp the effect of each programme on the variables under study. Cohen's *d* was taken as size effect value.

Results

A total of 15 people in EF group (average age 67.64 ± 4.37 years; 73.3% women) and 22 people in EC group (average age 66.67 ± 3.85 years; 77.3% women) volunteered for the study and provided valuable data, after attending more than 80% of the sessions and completing the post-intervention measurements. Statistical analysis showed that the groups were homogeneous at baseline. The results obtained after both programmes were carried out showed that participants in both groups significantly improved their aerobic capacity and cognitive function (Table 2), but only those of EC group experienced significant changes in dynamic balance. A comparative study using ANOVA 2x2 (Moment x Group) suggested the existence of a differential effect depending on the programme and the variables which were assessed by means of SDMT, $F (1.44) = 4.037$; $p = 0.038$ and TUG, $F (1.44) = 3.120$; $p = 0.045$.

Discussion

The results of this study show that both programmes resulted in comparable improvements in aerobic capacity, which was in some way to be expected, given that both interventions featured exercises with an aerobic component, both on land and in the aquatic environment. Previous studies have found that water-based exercises and land-based performance may lead to significant improvements at the aerobic level in healthy older adults either separately[11], or in combination[12]. Similarly, it has been argued that water-based exercise performance translates into significant improvements in dynamic balance in healthy older adults, since the aquatic environment may create positive adaptations in dynamic balance, possibly through the continuous instability applied to the subject who keeps exercising in an upright position[13]. Nevertheless, in spite of showing a slight improvement in their dynamic balance, only those participants from group EC who underwent cognitive training managed to increase it in a significant way. Therefore, it could be thought that the difference might have been due to the practical application of cognitive exercises taken from the BrainGym® programme. Indeed, BrainGym® exercises require fine motor involvement, balance and coordination, which are factors that have a direct repercussion on dynamic balance. In this sense, it could be hypothesised that performing these types of exercises might have stimulated the brain executive function, which seems to play a key role in gait and balance in older adults[14]. In this respect, further studies are needed.

Table 1. Exercise interventions.

Land-based exercise	Water-based exercise	
Callisthenic	**Callisthenic**	**Brain gym**
Warm-up exercises (10 min)	***Warm-up exercises (15 min)***	***Warm-up exercises (15 min)***
Aerobic work (5 min) Walking in different directions, following the monitor's instructions. Articular mobility (5 min) Ankle, knee, hip, and cervical column rotation. Shoulder rolls. Flexion and extension of ankles, knees, shoulders and cervical column. Torso rotations. Sets: 2 complete sequences. Duration: each exercise lasts for 30-45s. Sequence: following the established order.	Articular mobility (15 min) While sitting at the edge of the pool: Ankle rotation. Flexion/extension of knees. Shoulder rolls. Freestyle leg stroke, in the water, with extended knees. Clap below lifted leg. Torso rotation with flexed knees and legs together. Stirring the water in circles with the arms extended. Backward and forward pedalling in the water. Opening and closing one's legs underwater. Sets: 2 complete sequences. Duration: each exercise lasts for 30-45s. Sequence: following the established order.	Articular mobility (15 min) While sitting at the edge of the pool: Ankle rotation. Flexion/extension of knees. Shoulder rolls. Freestyle leg stroke, in the water, with extended knees. Clap below lifted leg. Torso rotation with flexed knees and legs together. Stirring the water in circles with the arms extended. Backward and forward pedalling in the water. Opening and closing one's legs underwater. (9) Sets: 2 complete sequences. Duration: each exercise lasts for 30-45s. Sequence: following the established order.
Main part (35 min)	***Main part (35 min)***	***Main part (35 min)***
Aerobic capacity (20 min) Moving along with the music (110-120 beats/min) and following the monitor's indications: Quick-slow Knee-lifting Calf-pump Lateral movements Changes in direction	Aerobic capacity (20 min) Different swimming styles supervised by the monitor using safety implements (boards, inflatable armbands, pull-boys, and lifejackets).	Brain Gym (6 min) The owl (adapted). Lazy Eight (adapted). Sets: 3 complete sequences. Duration: each exercise lasts 45-60s. Sequence: following the established order.
Coordination/balance (5 min) Displacements holding the ball following the prescribed route. Same as before, bouncing the ball as one walks. In a stationary position, throwing the ball in the air and picking it up without changing position. Sets: 2 complete sequences. Duration: each exercise lasts 30-45s. Sequence: following the established order.	Coordination/ balance (5 min) Displacements from one side to the other of the shallow pool, arms stretched out. Staying in place in the centre of the pool. Displacements from one side to the other of the shallow pool following the prescribed route. Sets: 2 complete sequences. Duration: each exercise lasts 30-45s. Sequence: following the established order.	Aerobic capacity (10 min) Different swimming styles supervised by the monitor using safety implements (boards, inflatable armbands, pull-boys, and lifejackets).

Strength-resistance (10 min) Throwing the ball and picking it up individually. Bouncing the ball hard against the floor changing from the right hand to the left. Pressing the ball between one's hands. Holding the ball between one's legs, preventing it from falling down to the floor. *Sets: 3 complete sequences.* *Duration: each exercise lasts 30-45 s.* *Sequence: following the established order.*	Strength-resistance (10 min) Small jumps at the edge of the pool. Pushing water away with the palm of one's hand. Knee-lifts, trying to reach one's chest. Keeping afloat with the arms only, trying not to use one's feet. Three small jumps followed by a longer jump clapping both hands below one's legs. *Sets: 2 complete sequences.* *Duration: each exercise lasts 30-45 s.* *Sequence: following the established order.*	Brain Gym (6 min) Double Doodle (adapted). Sideways crawling (adapted). Lazy Eight (adapted). Sets: 2 complete sequences. Duration: each exercise lasts 45-60 s. Sequence: following the established order.
		Coordination/balance (5 min) Displacements from one side to the other of the shallow pool, arms stretched out. Staying in place in the centre of the pool. Displacements from one side to the other of the shallow pool following the prescribed route. Sets: 2 complete sequences. Duration: each exercise lasts 30-45 s. Sequence: following the established order.
		Brain Gym: (8 min) Energetic yawn Cook anchoring (adapted) Brain buttons (adapted) Hat Sets: 2 complete sequences. Duration: each exercise lasts 45-60 s. Sequence: following the established order.
Cooling-off activities (15 min)	***Cooling-off activities (10 min)***	***Cooling-off activities (10 min)***
General stretching exercises (10 min) Quadriceps. Biceps Gastrocnemius muscles Triceps Adductors Trapezius Pectoral Latissimus dorsi muscle Sets: 1 complete series. Duration: each exercise lasts 15-25 s. Sequence: following the established order.	Muscle stretching in the water at the edge of the pool (5 min) Quadriceps Triceps Gastrocnemius muscles Pectoral Latissimus dorsi muscle Sets: 1 complete series. Duration: each exercise lasts 15-25 s. Sequence: following the established order.	Muscle stretching in the water at the edge of the pool (5 min) Quadriceps Triceps Gastrocnemius muscles Pectoral Latissimus dorsi muscle Sets: 1 complete series. Duration: each exercise lasts 15-25 s. Sequence: following the established order.
Exercises to control breathing and relaxation, lying down or standing up (5 min).	Relaxation exercises lying face down on floating mats (5 min).	Relaxation exercises lying face down on floating mats (5 min).

Table 2. Effects of the programmes implemented on cognitive functions, aerobic capacity and dynamic balance (Univariate analysis).

	EF Group		**EC Group**			
	Pre	**Post**	**Pre**	**Post**	**ANOVA (Moment x Program)**	**Effect Size**
Symbol Digit Modalities Test (SDMT)	17.64 ± 10.03	22.70 ± 14.08*	17.93 ± 8.47	26.20 ± 9.58**	$F_{1.44}$ = 4.037; p = 0.038	0.561
2-Minute Step	94.00 ± 11.59	99.80 ± 18.84*	90.20 ± 22.69	91.09 ± 17.86*	$F_{1.44}$ = 0.187; p = 0.667	0.138
Timed Up and Go (TUG)	6.08 ± 1.72	5.84 ± 1.65	5.40 ± 0.68	5.12 ± 0.65*	$F_{1.44}$ = 3.120; p = 0.045	0.369

Note: ANOVA (Moment x Program) with Bonferroni corrections for post hoc tests was used. *Student's paired t test p < 0.05; ** Student's paired t test p < 0.001

As regards the perceived effects on cognitive function, the results of this study suggest that both exercise programmes led to significant improvements, which might have been due to their design. Firstly, all participants performed the exercises aimed at stimulating aerobic capacity, thus the amelioration in cognitive function could have been at the expense of this increase. In this regard, the usefulness of aerobic exercise to improve performance in multiple cognitive functions such as processing speed, executive functions or working memory has been highlighted. These improvements might come as a consequence of certain effects exercise performance seems to have at a neurological level, such as higher cerebral perfusion, enhanced neurogenesis, synaptogenesis and angiogenesis, an increased concentration of brain derived neurotrophic factor and changes in brain structure[15]. Secondly, there has been discussion on the potentially positive effects of water-based exercises on cognitive function, given the particular features of the aquatic environment[16]. To the best of our knowledge, only two recent pieces of research to date have provided evidence of the beneficial effects of water-based exercise on the cognitive function of the elderly. Both papers were published after the present study was carried out. In this vein, Fedor[4] found that one week of water aerobics produced significant increases in the executive function, attention, and memory performance of community dwelling older adults. Similarly, Sato[17] observed that a weekly water-based exercise programme (including water cognitive tasks) for the duration of ten weeks, improved several cognitive functions, such as attention and memory in healthy elderly people. Finally, the combination of water-based and land-based exercise that has been administered in the present research seems to be an adequate protocol for the induction of improvements in the cognitive functions of healthy older adults, judging by the evidence gathered by one of the very few studies carried out on the subject[18].

Furthermore, it is relevant to comment that when comparing the magnitude of the effect of both programmes on cognitive function, it was observed that participants who performed water-based cognitive exercises experimented a significantly higher improvement in their cognitive function, an aspect that Sato[17] corroborated, and which may well be related to the BrainGym® practice suggested in this study. According to its founders, regular performance of Brain Gym® results in the stimulation and integration of different parts of the brain, especially the corpus callosum, which, in the long run, makes communication between the two hemispheres faster and more integrated for high level reasoning[10]. However, its theoretical underpinning has also been subject to criticism by neuroscientists and by educators with expertise in neuroscience and cognition[19]. Nonetheless, scientific evidence is contradictory. Some authors have found that practice of BrainGym® led to significant improvements in the cognitive functions of old people with dementia[20], as it did in the elderly with no previous history of cognitive problems[21]. In spite of this, another study did not observe any remarkable effect on cognitive performance in healthy older adult populations who took part in a physical exercise programme designed along the same lines as the present study, although BrainGym® sessions were land-based rather than water-based[12]. Thus, it could be hypothesised that the BrainGym® adaptations carried out in the aquatic environment could result in a maximisation of its alleged beneficial effects on the cognitive function of healthy older adults. Keeping this in mind, further research seems to be necessary. In spite of this, it should be noted that cognitively healthy people may attest a limited scope for improvement, especially in short-term interventions like the one described in the present study. Thus, it is important to remark that the sample in this study showed SDMT scores which might be considered low[22]; consequently, both interventions may have had a significant effect on the variables under assessment more easily. Perhaps if participants had departed from a higher level in that test, the programme effect on cognition might have been much lower.

There are several limitations to this study. Firstly, the results were not compared against a control group. Secondly, sample size was small. Thirdly, group distribution was not randomized. Fourthly, influence of a learning effect on SDMT should not be ruled out, given the short length of the intervention and the good cognitive state of the sample. Finally, participants were already inclined towards physical activity and chose the programme of their own volition, which is why the final number of subjects per group was not homogeneous. These methodological weaknesses limit both generalisation and extrapolation of the results presented in this paper.

Conclusions

In closing, the results of this study suggest that the combination of water-based and land-based physical exercise may give way to improvements in cognitive functions and fitness levels in healthy older adults. The inclusion of cognitive exercises carried out in the aquatic environment seems to maximise these effects.

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Acknowledgements

The authors would like to thank all older adults for their time and participation. Much gratitude is also reserved for the sports staff for their enthusiasm towards the project.

Funding

This work was supported by the programme "I2C" Consellería de Cultura, Educación e Ordenación Universitaria. Xunta de Galicia, Spain (grant no. R2014/031).

Corresponding author

José Mª Cancela Carral. Faculty of Education and Sports Science (University of Vigo), Campus a Xunqueira S/N, CP 36005, Pontevedra. Spain.
Email: chemacc@uvigo.es

Manuscript received on October 26, 2016
Manuscript accepted on March 8, 2017