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Effects of dual-task aquatic exercises on functional mobility, balance and gait of individuals with Parkinson's disease: A randomized clinical trial with a 3-month follow-up

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ABSTRACT

Objective: To evaluate the effects of dual-task aquatic exercises on functional mobility, balance and gait of individuals with Parkinson's disease (PD).

Design: A randomized, single-blind trial was used. Twenty-eight (28) individuals met the inclusion criteria and were randomized in the Experimental Group (EG) and Control Group (CG). EG was subjected to a dual-task aquatic exercise program, twice a week for 10 weeks. Each session lasted 40 min, in a heated pool (33 °C). The individuals were assessed at the beginning (AS1), after an exercise program (AS2), and after a three-month follow-up (AS3). Functional mobility ("Timed Up & Go" Test, and "Five Times Sit to Stand" Test), balance (Berg Balance Scale) and gait (Dynamic Gait Index) were verified.

Results: 25 individuals were analyzed (14 EG and 11 CG). There was a time-group effect of the EG when compared to the CG: TUG ($p = 0.03$ and $p = 0.015$ to AS2 and AS3), FTSST ($p = 0.001$ and $p = 0.004$, for AS2 and AS3), BBS ($p = 0.002$ and $p = 0.002$, for AS2 and AS3), DGI ($p = 0.001$ and $p = 0.003$, for AS2 and AS3).

Conclusions: The suggested dual-task aquatic exercise program was able to improve functional mobility, balance and gait of individuals with PD, which shows that such type of exercise is a promising possibility of therapy.

1. Introduction

Parkinson's disease (PD) is a chronic, neurodegenerative disease characterized by the death of dopaminergic neurons of the substantia nigra in the midbrain.[1] These neurons, along with others, are responsible for motor control, which is the ability to regulate or guide the mechanisms essential to movement. Thus, there is a change in motor activities that involve functional mobility, such as ambulation, transfers, self-care, and balance, among others.[2] With the progression of PD, there are changes in the processing of vestibular, visual and proprioceptive signals, which maintain body balance.[3] PD patients tend to move their center of gravity forward, making it difficult for them to perform compensatory movements and adjustments of such body balance, which leads to more frequent falls.[3] There is also gait impairment with changes in spatio-temporal and angular variables, such as decrease in speed and gait length,[4] as well as upper limb balance and compensations in cadence and variability pace. This leads to a decrease in hip extension range, knee flexion and plantar flexion.[5]

Frequently, in everyday activities, we have to perform cognitive-motor tasks simultaneously – such as driving while talking, walking while speaking, listening while writing – in which the attention of the individual is divided.[6] Such concomitant acts demand an ongoing interaction between neural processing and the practice of tasks, named "dual task".[6] Research suggests that deficits in the performance of the dual task in PD individuals can generate normal movement patterns when they focus on performance, that is, they think to execute the movements.[7] Thus, they activate the intact region of the premotor cortex without resorting to deficit circuit of the basal ganglia, which help in the production of movement, resulting in the loss of motor control automaticity in tasks such as walking.[8] In dual-task conditions, the use of these cortical resources to perform motor tasks can compromise both performances. This impairment in the primary and/or the secondary tasks occurs because the two tasks compete for similar demands for their processing.[8]

The move from the terrestrial to the aquatic exercise environment can stimulate an increase of strategies and bodily adjustments for the execution of different motor skills, thus improving the quality of the

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motor behavior.[9] Swimming exercises in a heated pool stimulate situations of corporal instability, which leads to the acquisition of body straightening and balance reactions.[9] This reduces the risk of falls, in addition to promoting physiological and therapeutic benefits such as relaxation and decreased pain, which favors functional mobility.[9,10] The effects of aquatic exercises are obtained through proper use of the physical and thermal properties of this medium, such as keeping temperature above 33 °C and combining principles like Archimedes, Pascal, water resistance, among others.[11]

Both dual-task training and aquatic exercises show benefits in individuals with PD. In this way, it is possible to consider how a cognitive task combined with a motor activity may allow participants to advance their functional mobility, balance, and gait when taking place in an aquatic environment. This is because the repetition of multidirectional steps, turns, and changes in weight and posture enable individuals to direct their attention and to acquire specific skills that are necessary for making tridimensional movements in water.

However, studies and knowledge about dual-task practice in the aquatic environment are still scarce. Therefore, this study aims to verify the effects of a dual-task aquatic exercise program on functional mobility, balance and gait of individuals with PD.

2. Methods

This research is based on a randomized, single-blinded clinical trial. The study is stored in the Brazilian Clinical Trials Registry, number RBR-8cxzf2. The study was also approved by a Research Ethics Committee, and conducted according to the Declaration of Helsinki principles. This study conforms to all CONSORT guidelines and reports the required information accordingly (see Supplementary Checklist).

2.1. Participants

The sample calculation was performed by GPower 3.1 software,[12] which stipulated a minimum sample of 30 individuals, assuming an effect size of 0.25 on a probability distribution F, whose value consists of a mean distance between the sample mean and the population mean; Type I error equivalent to 0.05 and analysis power equal to 0.84.

All the participants signed an informed consent term, agreeing to participate in the research. Patients of both genders were considered eligible, with clinical diagnosis of idiopathic PD; eligible participants were also in stages 1 to 4 in the Hoehn and Yahr scale and had a medical certificate to perform aquatic exercises and to use a heated swimming pool. The following individuals were excluded from the study: 1) Individuals who did not present independent gait (whether or not this was related to PD); 2) individuals who were diagnosed with another disease that could interfere in the physical assessments (for example, patients with body balance alterations of vestibular origin); 3) individuals with visual or auditory impairment, who were unable to follow verbal and visual instructions (determined by Mini-Mental State Examination); 4) individuals that have contraindications to use a heated swimming pool, such as fever, incontinence, severe blood pressure change, and open wounds; 5) individuals who presented alterations in the parameters of medication intake, based on Levodopa, during the study period; or 6) individuals who did not agree with the informed consent term.

2.2. Procedures

Individuals were recruited in January 2016, by convenience and willingness, at “Association of Parkinson's Disease Patients in the state of Paraná - Brazil”. The evaluations were conducted by physiotherapists who did not participate in the intervention program. They were submitted to ICC (Intraclass Correlation Coefficient) and presented good reproducibility of the evaluation criteria (both intra-rater and inter-rater), with values of 0.887 and 0.754, respectively.

The evaluations occurred in three sessions: initial assessment (AS1), in January, 2016; assessment at the end of the intervention program (AS2), three months later; and assessment three months after the AS2 (AS3), which corresponds to the detraining period of the EG. After AS1, the subjects were randomized into either the Experimental Group (EG) or Control Group (CG) by using sealed envelopes.

2.3. Outcomes measures

To evaluate functional mobility, the “Timed Up & Go” (TUG) Test and the “Five Times Sit to Stand” Test (FTSST) were used. TUG measures, in seconds, the time required for an individual to rise from a common armchair, walk a distance of 3 m, turn around, walk back to the chair and sit down again.[12] The time over 16 s is related to the risk of falls in individuals with PD Hoehn Yahr stage 1–4.[13] FTSST is performed by requesting that the participant remain seated with arms crossed in front of the body, over the chest; upon signaling, s/he has to stand up in an erect position, with complete extension of knees and hips, and then must return to the seated position. The participant must repeat this exercise five times uninterruptedly, and the amount of time spent is timed.[13] The time over 16 s is related to the risk of falls in individuals with PD. To assess balance, including stable and anticipatory postural control, the Berg Balance Scale (BBS) was used. Such a scale requires different forces, dynamic balance and flexibility.[14] The BBS has a maximum score of 56. Each item has an ordinal scale with 5 options, which vary from 0 to 4 points (where 0 is the lowest and 4 is the highest possible score for performance). The test is simple, easy to administer, and safe for the assessment of elderly patients. It only requires a stopwatch and a ruler, and it lasts around 15 min.[14] A result equal to or lower than 47 points indicates a risk of fall for individuals with PD.[15] Finally, the Dynamic Gait Index (DGI) was used to analyze the gait and dynamic posture. It consists of eight tasks involving gait in different sensory contexts including: flat surface, changes in gait speed, horizontal and vertical movements of the head, going over and getting around obstacles, turning on one’s own body axis, going up and down stairs.[16] Points vary from 0 to 3 in each item (where 0 is the lowest and 3 is the highest possible performance score). A score that is equal to or lower than 19 points indicates a risk of fall for individuals with PD.[15]

All assessments were done by the same physiotherapist trained on scales and assessment tests, in assessment 1 (AS1), in assessment 2 (AS2) and in assessment 3 (AS3). This evaluator was independent of the physiotherapist applying the intervention program.

All instruments are currently recommended for assessment in PD by the European Physiotherapy Guidelines for Parkinson's Disease[15] and were randomized to not create an ordered effect.

2.4. Intervention

The intervention occurred for the EG over 20 sessions, twice a week, each session lasting 1 h (10 min to measure initial and final vital signs, and 50 min of immersion and exercises). The activities were performed in groups of 7–8 participants, composed of 2 groups in subsequent hours, on the same days of the week (Tuesday and Friday) with the same duration and exercise content. Recent studies[17,18] and systematic review[19] indicate that exercise programs from 8 to 12 weeks have an effect on functional variables of individuals with PD. Similarly, the length of each session in these programs has varied from 30 to 60 min. Therefore, we designed our intervention program based on these findings.

Dual-task aquatic exercises were proposed. The intervention was previously outlined in order to follow an increasing sequence of complexity, aimed at the gradual progression of difficulty. The progression occurred if patients were able to successfully complete a task another task was added. First of all, they performed the primary motor task (from standing up and walking to activities such as running, adopting unstable postures and making rotations) and the dual-task activity of less difficulty, thus passing to the more complex dual task activity (from

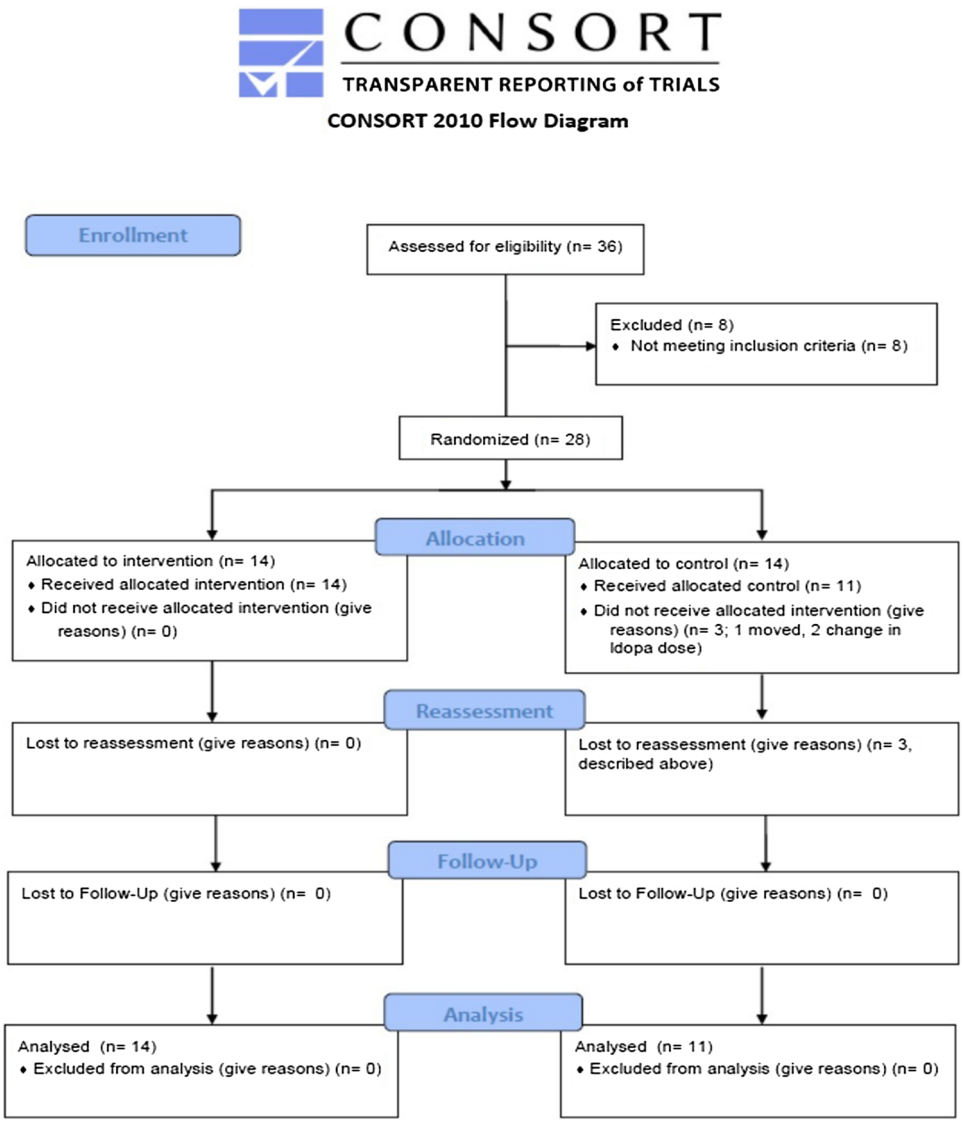

Fig. 1. Consort diagram.

activities such as holding or carrying objects to others involving memory retrieval and mental calculations). Each exercise, described in Appendix 1, was performed approximately for 4 min.

The CG was instructed to keep their current activities, without going through any exercise program. All patients (EG and CG) were assessed and performed all exercises (only EG) during the on phase of L-dopa.

2.5. Statistical analysis

The data were evaluated considering the residual distribution pattern (the Shapiro-Wilk test was used). The initial characteristics of the participants were compared by Student's *t*-tests. For comparison between the groups (EG and CG) and between the assessments (1–3) a repeated measures ANOVA was used. Bonferroni's post hoc test was used for multiple comparisons. Statistica 7 software was used.

3. Results

The selection and exclusion process of the sample is shown in Fig. 1. A total of 36 individuals with PD were evaluated in the APPP, however, only 28 initially attended the inclusion criteria, while the other 8 were excluded for presenting one or more exclusion criteria. There is no difference in baseline groups. After randomization, 14 individuals composed the EG and effectively finished the research, while in the CG, composed initially by 14 individuals, there were 3 exclusions (1 because of moving to another city and 2 because of changes in the L-dopa dose). At the end, 25 individuals were analyzed.

The values referring to the average age, time of diagnosis and classification by Hoehn & Yahr scale are reported in Table 1.

3.1. Functional mobility

Regarding the evaluation through the TUG test, there was difference between the times ($p = 0.03$ for AS2 and $p = 0.015$ to AS3), which means a reduction in the time taken for completion of the TUG by the EG. In the FTSST, it was observed that there was also difference between the EG and CG ($p = 0.001$ for AS2 and $p = 0.004$ for AS3), resulting in a decrease in time for completion of the FTSST. The results are described in Table 2.

3.2. Balance

It was observed that there was difference in the "time" and "group" factors ($p = 0.002$ for AS2 and AS3), which results in higher score and better balance for the EG in comparison with the CG.

Table 1
Descriptive statistics for baseline information.

	Experimental Group	Control Group	P
Sample size	14 (8 women, 6 men) men)	11 (6 women, 5 men)	0,793
Age (years)	63,12 ± 13,61	64,23 ± 13,45	0.153
H&Y	3 ± 1	3 ± 1	0.211
UPDRS section III	17,53 ± 6,59	16,45 ± 6,23	0.472
TUG (seconds)	15.69 ± 5.55	14.33 ± 5.51	0.962
FTSST (seconds)	20.21 ± 3.27	17.58 ± 3.28	0.784
BBS	44.23 ± 4.25	45.36 ± 4.40	0.298
DGI	16.85 ± 2.66	18.82 ± 3.50	0.203

Results from Shapiro-Wilk test. Legend: H&Y- classification of PD in Hoehn & Yahr staging; TUG-Timed Up and Go Test; FTSST-Five times Sit to Stand Test; BBS-Berg Balance Scale; DGI-Dynamic Gait Index. All data are reported as mean ± SD. P = values of initial assessment from Student's *t*-test ($p > 0.05$).

3.3. Gait

Regarding gait assessment using DGI, it was observed that there was a significant statistical difference in the "time" and "group" factors ($p = 0.001$ for AS2 and $p = 0.003$ for AS3). That is, it was verified a higher score and better gait performance for the EG in relation to the CG.

4. Discussion

In our research, 25 individuals completed the study, with a sample loss of more than 20%. Similar studies are being conducted in subjects with PD, and feature similar sample sizes.[20,21] As in the case of the present investigation, sample loss has also occurred in such studies.[5,20] We stress that the studies with sample losses, such as ours, have a passive CG (when the group did not undergo any kind of intervention). Studies comparing two or more types of intervention showed no sample loss after groups randomization.[22,23] Regarding the average age and the time of diagnosis of the study, research with aquatic exercise and PD have indicated a mean that is either similar or slightly above the one presented in this study.[22,24]. As for the Hoehn & Yahr scale, studies have presented individuals in stage 2, which differs from ours, in which the majority was in stage 3 of the disease.[21,22]

Results obtained on functional mobility indicated an improvement of the EG in AS2, which remained in AS3, differing from the CG, which worsened over time. Studies have shown that aquatic exercises promote improvements in mobility (through the means of TUG), whether or not they are compared with other aquatic exercises[2] or with terrestrial ones[22] (also perceived through the FTSST measure). More importantly, these clinical assessments can show improvements in our experimental group when compared with the control group, indicating that functional movement in an aquatic environment improves balance as well as dynamic movement ability.[11] The functional mobility can be complementarily treated in the aquatic environment, in which the water resistances, such as viscosity and turbulence, can promote gains in mobility.[2]

As for balance, good results have been reported after aquatic training. Research indicates improvement both immediately after the exercise program[17] and even after a retention period.[21]

Another variable analyzed in our study is gait in PD, which benefits from intervention programs. Aquatic exercises presented improvements[21] that, due to the peculiarities of the aquatic environment, promote restrictions to the individual, leading to adaptations that generate effects on motor learning. That happens because the environmental restrictor forces the individual to either learn a new sequence of movements or adapt to the demand of a task that is different from the habitual one.[25,26] The improvement of gait in aquatic environment is also due to the fact that it is a safe environment, which reduces fear of falling[9] and stimulates participation and affiliation of individuals.[11]

The only study in the current literature which found effects of dual-task aquatic exercise, even though in a different population (stroke), presented a significant difference in mobility, balance and gait of individuals.[27] Such results suggest that the therapeutic benefits of water associated with dual-task training promote motor learning and neuroplasticity of the individuals with PD that participated in the presented study. We stress that, in all the variables studied, the increases due to the treatment remained even after the detraining period, which indicates that 10 weeks of intervention promoted a retention period of motor learning in these individuals.

Thus, our study reinforces the idea that physical exercise with cognitive demand can strengthen and improve motor circuits, through mechanisms that include the increase in synaptic strength resulting from dopamine and glutamate neurotransmission raised in basal ganglia, accompanied by increase of dendritic spine formation.[28] The exercise leads to widespread brain health improvement, including increased expression of neurotrophic factors, increased blood flow and increased neurogenesis, especially in the hippocampus. Such changes can lead to enhanced neuronal circuits between the basal ganglia and their cortical and thalamic connections, which ultimately results in improvement of motor, non-motor and cognitive behavior in individuals with PD.[28]

4.1. Study limitations

The absence of exercise groups, whether aquatic or terrestrial, single and dual tasks groups limits the understanding of the real benefits of the proposed intervention program, specially the dual task effects. Only clinical outcomes measures were used in order to facilitate access and repeatability for the largest possible number of professionals. However, more refined research tools could be associated with the functional assessments. It is necessary that further research is conducted in similar situations in order for the effects to be verified and better known.

5. Conclusion

The aquatic exercise program improved the functional mobility, balance and gait of people with PD. The aquatic dual task exercise needs more study for better understand their benefits in functional and physical assessments, regarding mobility, balance and gait, considering the possible benefits of combining the characteristics of each workout for this specific group.

Table 2
Descriptive statistics of aquatic dual-task training.

	Experimental			Control		
	AS1	AS2	AS3	AS1	AS2	AS3
TUG	15.69 ± 5.55s	13.17 ± 3.23 s[a,b]	13.31 ± 2.83s[b]	14.33 ± 5.51s	15.58 ± 3.65s	16.68 ± 3.42s
FTSST	20.21 ± 3.27s	15.57 ± 2.22s[a,b]	16.35 ± 2.14s[b]	17.58 ± 3.28s	19.39 ± 2.59s	20.55 ± 2.51s
BBS	44.23 ± 4.25s	49.62 ± 4.01s[a,b]	47.38 ± 2.82s[a,b]	45.36 ± 4.40s	42.91 ± 6.35s*	42.36 ± 5.04s
DGI	16.85 ± 2.66s	21.54 ± 1.82s[a,b]	20.15 ± 1.23 s[b]	18.82 ± 3.50s	17.00 ± 3.71s	17.36 ± 2.28s

Values are reported as mean ± SD (range).
[a] Significant difference compared to previous assessment.
[b] Significant difference intergroups; s = seconds.

Conflict of interest

The Authors declare that there is no conflict of interest.

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Appendix 1

Aquatic dual task exercise program.

Weeks 1-2

Individual exercises	Group exercises
Walk; Walk while moving upper limbs (flexion and extension until reaching the water level; Abduction and adduction until reaching the water level); Walk while saying fruit names; Walk while saying color names. 30 seconds rest between exercises	Standing in line while passing the ball to the person behind; In a circle, passes the ball to the person beside (with both hands); In a circle, passes the ball to the person beside (receives it with one hand and passes it with the other); In a circle, passes the ball to the person beside while counting in sequence (starting with 0, increasing 2 for each person); In a circle, passes the ball to the person beside while counting in sequence (starting with 100, decreasing 2 for each person). 30 seconds rest between exercises

Weeks 3-4

Individual exercises	Group exercises
Walk; Walk while moving upper limbs (flexion and extension until reaching the water level; Abduction and adduction until reaching the water level); Walk and hold a board in front of the body, keeping it submerged; Tandem gait; Backwards tandem gait. 30 seconds rest between exercises	Standing in line while passing the ball to the person behind; In a circle, passes the ball to the person beside (with both hands); In a circle, passes the ball to the person beside (receives it with one hand and passes it with the other); In a circle, passes the ball to the person beside while counting in sequence (starting with 0, increasing 2 for each person); In a circle, passes the ball to the person beside while counting in sequence (starting with 100, decreasing 2 for each person). 30 seconds rest between exercises

Weeks 5-6

Individual exercises	Group exercises
Walk while moving upper limbs with water dumbbells (flexion and extension until reaching the water level; abduction and adduction until reaching the water level); Walk and hold a board in front of the body, keeping it submerged; Tandem gait; Backwards tandem gait. 30 seconds rest between exercises	Standing in line performing single-leg stance while passing the ball to the person behind; In a circle, passes the ball to the person beside while moving in lateral gait to the same direction of the ball; In a circle, counts in sequence (starting with 0, increasing 3 for each person) while moving in lateral gait to the direction of the counting; In a circle, counts in sequence (starting with 100, decreasing 3 for each person) while moving in lateral gait to the direction of the counting. 30 seconds rest between exercises

Weeks 7-8

Individual exercises	Group exercises
Walk while moving upper limbs with water dumbbells (flexion and extension until the water level; Abduction and adduction until the water level); Tandem gait with dumbbells in the upper limbs (kept submerged and parallel to the body); Backwards tandem gait with dumbbells in the upper limbs (kept submerged and parallel to the body). 30 seconds rest between exercises	Standing in line performing single-leg stance while passing the ball to the person behind and saying his/her name; In a circle, passes the ball to the person beside while moving in lateral gait to the opposite direction of the ball; In a circle, counts in sequence (starting with 0, increasing 3 for each person) while moving in lateral gait to the opposite direction of the counting; In a circle, counts in sequence (starting with 100, decreasing 3 for each person) while moving in lateral gait to the opposite direction of the counting. 30 seconds rest between exercises

Weeks 9-10

Individual exercises	Group exercises
Walk while moving upper limbs with water dumbbells (flexion and extension until reaching the water level; Abduction and adduction until reaching the water level) and crossing plateaus (climbing, walking on it and down); Tandem gait with dumbbells in the upper limbs (kept submerged and parallel to the body) and, upon hearing one whistle the person should walk looking to the right, upon hearing two whistles he/she should walk looking to the left, and upon hearing three whistles he/she should stop; Backwards tandem gait with dumbbells in the upper limbs (kept submerged and parallel to the body) and, upon hearing one whistle the person should walk looking to the right, upon hearing two whistles he/she should walk looking to the left, and upon hearing three whistles he/she should stop. 30 seconds rest between exercises	Standing in line performing single-leg stance with eyes closed while passing the ball to the person behind and saying his/her name; In a circle, passes the ball to the person beside while moving in lateral gait to the opposite direction of the ball, with 3 balls inserted in the circle; In a circle, counts in sequence (starting with 0, increasing 3 for each person) while moving in lateral gait on tiptoe (plantar flexion) to the opposite direction of the counting; In a circle, counts in sequence (starting with 100, decreasing 3 for each person) while moving in lateral gait on tiptoe (plantar flexion) to the opposite direction of the counting. 30 seconds rest between exercises

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