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Effects of a multimodal exercise program in motor fitness and functional motor asymmetry: Study with Portuguese older adults of different contexts

KEYWORDS:

Aging. Older adults. Exercise program. Motor fitness. Functional motor asymmetry.

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ABSTRACT

The effect of a multimodal exercise program in motor fitness and functional motor asymmetry in two groups of older adults ($n = 112$) was investigated. The experimental group ($n = 72$) was comprised of participants from a hospital center ($n = 19$), a residential care home ($n = 26$), and a daily living center ($n = 27$). The control group ($n = 40$) included participants from a residential care home with mental health disorders ($n = 8$), an residential care home ($n = 16$), and a daily living center ($n = 16$). The participant's hand, preferred (PH) and non-preferred (NPH), and both hands (BH), were assessed with the *Purdue Pegboard Test*, the *Minnesota Manual Dexterity Test,* and the *Discrimination Weights Test* in the following abilities, respectively: dexterity (fine and global) and proprioceptive sensitivity. Results revealed a positive significant effect of the exercise program, for all tasks, with participants improving their performance from pre- to post-training ($p < .050$). For example, concerning global dexterity, in the experimental group of the hospital center, a significant main effect was found for time with the PH ($F_{1,11} = 12.296$; $p = .005$), the NPH ($F_{1,11} = 5.057$; $p = .046$), and BH ($F_{1,11} = 6.777$; $p = .025$). The opposite occured in the control group with the residential care home (older adults with mental health disorders). There was a significant decrease in performance from pre-training (PH: 140.11 ± 31.72 s; NPH: 150.33 ± 24.62 s) to post-training (PH: 162.41 ± 39.37 s; NPH: 175.32 ± 31.11s). Gender also had a significant effect, with females of the daily living center presenting a better performance on fine dexterity with the PH ($F_{1,19} = 4.829$; $p = .041$) and the NPH ($F_{1,19} = 6.899$; $p = .017$). Our data reinforces the importance of this type of program since it improves motor coordination, which is important for an independent lifestyle and thus for an older adult's quality of life.

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Efeitos de um programa de exercício multimodal na aptidão motora e na assimetria motora funcional:

Estudo com idosos portugueses de diferentes contextos.

RESUMO

O efeito de um programa de exercício multimodal e a assimetria motora funcional foram investigados em dois grupos de idosos (*n* = 112). O grupo experimental (*n* = 72) foi composto por participantes de um centro hospitalar (*n* = 19), de um lar para idosos (*n* = 26) e de um centro de dia (*n* = 27). O grupo de controlo (*n* = 40) incluiu participantes de um lar para idosos com perturbações mentais (*n* = 8), de um lar para idosos (*n* = 16) e de um centro de dia (*n* = 16). A mão preferida (MP), mão não preferida (MNP) e ambas as mãos (AM) foram avaliadas com o *Purdue Pegboard Test, the Minnesota Manual Dexterity Test* e o *Discrimination Weights Test* nas capacidades: destreza (fina e global), sensibilidade proprioceptiva, respectivamente. Os resultados revealaram um efeito estatisticamente significativo do programa de exercício para todas as tarefas, com os participantes a melhorarem a sua prestação do pré para o pós-treino ($p < .05$). Por exemplo, no que diz respeito à destreza global, no grupo experimental do centro hospitalar, um efeito estatisticamente significativo foi observado no tempo com a MP ($F_{1,11} = 12.296$; $p = .005$), com a MNP ($F_{1,11} = 5.057$; $p = .046$), e com AM ($F_{1,11} = 6.777$; $p = .025$). O oposto foi observado no grupo de controlo do lar para idosos (com perturbações mentais). Observou-se uma diminuição significativa no desempenho do pré (MP: 140.11 ± 31.72s; MNP: 150.33 ± 24.62s) para o pós-teste (MP: 162.41 ± 39.37s; MNP: 175.32 ± 31.11s). O género também demonstrou ter um efeito significativo, sendo que as mulheres do centro de dia apresentaram os melhores resultados na destreza manual fina com a MP ($F_{1,19} = 4.829$; $p = .041$) e com a MNP ($F_{1,19} = 6.899$; $p = .017$). Os nossos resultados reforçam a importância deste tipo de programa, uma vez que promovem a melhoria da coordenação motora, a qual tem importância no estilo de vida independente e, consequentemente, na qualidade de vida dos idosos.

PALAVRAS CHAVE:

Envelhecimento. Idosos. Programa de exercício.
Aptidão física. Assimetria motora funcional.

INTRODUCTION

Aging, along with its accompanying degeneration, is a normal phenomenon in current societies. In fact, the number of older adults (normal or with dementia) accessing rehabilitation and intermediate care services, either in hospital or at home, is rising and will continue to increase (Comas-Herrera, Wittenberg, Martin Knapp, & MRC-CFAS 2003). The aging process leads to a decline in various abilities that involve strength, sensorimotor functioning, proprioception, tactile sensitivity, manual and pedal dexterity, and reaction time. This degeneration affects many daily life activities and, as a consequence, falls or accidents may occur that could be avoidable if older adults were to maintain good levels of motor fitness (Francis & Spidurso, 2000; Lord & St George, 2003). Besides overall functional fitness, the age-related changes in motor behavior are of great importance, although there is not much information or enough systematic investigation about manual dexterity and proprioceptive sensitivity. Therefore, this subject needs to be further studied to better understand the effects of exercise on these abilities in aged males and females.

The aim of the present study was to analyse older adults from a wide range of the population; that is, we sought to include older adults with mental health disorders (from a psychiatric hospital center [HC] and a residential care home [RCH]) and without mental health disorders (namely, from an RCH and a daily living center [DLC]). Thus, an investigation about this subject is pertinent, specifically at the level of some traits of motor fitness in its expression in older adults of both genders and from different contexts. The aim of the present study was to verify if a regular multimodal exercise program leads to the development of motor fitness in older adults from different contexts. The following hypotheses were formulated a priori: (a) a multimodal exercise program improves the motor fitness and changes functional motor asymmetry in older adults from different contexts, and (b) targeted interventions employing a multimodal exercise program (over 12 months in older adults from different contexts) are effective in males and females.

METHODS

SUBJECTS

A convenience sample of one hundred and thirty-six older adult participants from an HC, an RCH, and a DLC, participated in this study. The eligible subject pool was restricted to older adults from both genders with the following characteristics: aged ≥ 65 years, not engaged in any regular exercise training in the last year, older adults from an RCH and a DLC, lack of use of any medication known to affect balance, postural stability, and lack of any diagnosed or self-reported neurologic disorders or orthopedic medical conditions that contraindicate the participation in exercise and testing. We point out that the older adults from the HC and the RCH (older adults with mental health disorders) were previously diagnosed with neurological deficits by neurologists and gave their authorization to participate in the study. The sample, in each context, was divided into two groups: an experimental group (EG) with practice of the multimodal exercise program and a control group (CG). The control group is the follow up of a group where the intervention will not be performed. This aims to establish a causality inference by comparison, since an isolated data does not allow inferring whether its variability was determined by the intervention performed or by chance. The performance of the control group in relation to the dependent variable is used to evaluate the results obtained in the experimental group. The use of a control group prevents changes in study results from external elements (Polit & Beck, 2011). We try to compose the sample with an identical number of older adult participants in each context according to the gender and age; however, in some circumstances this proceeding was not possible. This was the case of HC and RCH (older adults with mental health disorders), contexts where the number of subjects in each group was different. Some older adults were excluded due to medical reasons: in the EG, four males and two females from the HC, two males and two females from the RCH, and four males and two females from the DLC; in the CG, one male and one female from the RCH (mental health disorders), two males and three females from the RCH, and one female from the DLC.

Before conducting the study, all participants received a complete explanation of the purpose, risks, and procedures of the investigation, and provided their written informed consent. The characteristics of the participants of the study are shown in Table 1.

TABLE 1. Subject characteristics of experimental and control groups. Contexts, age and gender.

Experimental Group			**Control Group**		
Subjects	**Mean age (years)**	**Gender**	**Subjects**	**Mean age (years)**	**Gender**
HC (*n* = 8)	70.13 ± 4.85	M	RCH (mental health disorders) (*n* = 4)	79.25 ± 8.01	M
HC (*n* = 11)	69.91 ± 4.27	F	RCH (mental health disorders) (*n* = 4)	85.5 ± 4.93	F
RCH (*n* = 9)	80.00 ± 8.27	M	RCH (*n* = 8)	81.88 ± 3.64	M
RCH (*n* = 17)	83.88 ± 5.30	F	RCH (*n* = 8)	81.00 ± 3.16	F
DLC (*n* = 11)	71.73 ± 5.51	M	DLC (*n* = 8)	79.38 ± 7.15	M
DLC (*n* = 16)	72.19 ± 6.45	F	DLC (*n* = 8)	74.25 ± 8.27	F

HC (hospital center), RCH (residential care home), DLC (daily living center),
RCH (residential care home): older adults with mental health disorders, M (males) and F (females).

Older adults from the EG were submitted to a multimodal exercise program for a period of twelve months, while those in the CG maintained their normal physical activity routine. All measurements and the multimodal exercise program were performed by the same evaluator, together with teachers who graduated from the University of Porto, Portugal. We emphasize that they were the evaluators prior and after training in both groups (EG and CG). The investigation was in full compliance with the Helsinki declaration of 1975, as revised in 2004, and all methods and procedures were approved by the Institutional Review Board.

The 12-month multimodal training protocol was held three times per week and each session lasted about 60 min. All sessions were accompanied by the appropriate music considered relevant to the required activity and the participants' age. A physical education instructor with specialization in older adult training conducted the sessions. The exercise training was designed to promote the development of abilities, such as visuomotor coordination skills, flexibility, balance, strength, reaction time, speed of movements of the hands and feet, proprioceptive sensitivity, coincidence anticipation, and visuomotor memory, as well as emotional and social aspects and awareness of the benefits of regular physical exercise.

Each training session included three main components: initial, a 10-min light warm-up and stretching exercises; fundamental, 45 min of light- to moderate-intensity exercises for the development of the abilities previously mentioned, such as marching in place, stepping exercise at a speed of 40–60 beats per min using a 15-cm-high bench, heel-drops performed on a hard surface (a heel-drop consists of raising the body weight onto the toes and then letting it drop to the floor, keeping the knees locked and hips extended), muscular endurance exercises performed concentrically and eccentrically and involving the upper and lower limbs; strength training performed with elastic bands and dumbbells; balance training with static and dynamic exercises (e.g., walking in a straight line, walking heel to toe, using additional resources, such as, balls, balloons, gymnastic parachutes and ribbons, hoops, ropes and sticks); flexibility training involved the major muscle groups (quadriceps, back and chest) and agility training (visuomotor coordination) aimed at challenging hand-eye coordination, foot-eye coordination, dynamic balance, standing and leaning balance, and psychomotor performance (coincidence anticipation, proprioceptive sensitivity, visuomotor memory and reaction time), including ball games, relay races, dance movements, and obstacle courses; and, finally, 5 min of stretching. For the exercises in the second part of the session, for all the abilities mentioned above, the repetitions were increased from eight to fifteen and the number of sets increased to three.

Older adults handedness was determined using the Dutch Handedness Questionnaire (van Strien, 2002). Subjects were classified as right-handers or left-handers based on their score, which identified 110 strong right-handers (mean score of 29.62 ± 1.25, where 30 is maximal right-handedness) and two strong left-handers (mean score of 3.5 ± 2.12, where 0 is maximal left-handedness). Both right-handers' and left-handers' data were included in the analysis and, according to their handedness, subjects used the preferred hand (PH) and the non-preferred hand (NPH) in the tests. Additional items were added to the Lateral Preference Inventory (Coren, Porac, & Duncan, 1979) that provided a measure of handedness, footedness, vision, and hearing. Coren et al.'s measure of lateral preference has demonstrated a 92% concordance between self-reports and direct behavioral performance (Coren, 1993; Coren, Porac, & Duncan, 1979). To assess the subjects' global cognitive function, the Mini-Mental State Examination (MMSE) (Folstein, Robins, & Helzer, 1983) was applied. MMSE total score ranges from 0 to 30. According to this questionnaire, none of the participants had any cognitive impairment (RCH: mean score of 28.23 ± 2.11; DLC: mean score of 27.53 ± 2.43), except the older adults with mental health disorders of the experimental group and the control group, where the doctors confirmed pathologies like schizophrenia, dementia, and depression.

To quantify and verify if there was any change in the daily activities of the sample during the research period, the Modified Baecke Questionnaire (Pols et al. 1995) was completed before and after training. This questionnaire has been shown to generate valid and reliable classification scores for activity in older subjects providing a domestic, a sport, and a leisure-time activity score. The sum of the different scores gives the total activity of the subject. The questionnaires were completed by the same researcher during a personal interview. For ethical reasons, this questionnaire was not applied to all the older adults with mental health disorders of the experimental group and the control group.

INSTRUMENTS

According to the instruments applied, we describe the designs and procedures adopted. The Minnesota Manual Dexterity Test (MMDT, Lafayette instrument nº. 32023) (Lafayette Instrument Company, 1998) was used as an indicator of the manual global dexterity. The Placing Test includes one trial with each hand. The Turning Test assesses both hands (BH) with one trial, with a rest interval between tests of 1 min. Finally, the time to accomplish the test is recorded. The Purdue Pegboard Test (PPT, Lafayette instrument, nº. 32020) (Lafayette Instrument Company, 2002) was used as an indicator of the manual fine dexterity. Tests were conducted with the preferred hand (PH) for 30s, with the non-preferred hand (NPH) for 30s, and with both hands (BH) for 30s. The rest interval between the trials was 30s and between the tests was 1min. The subjects performed three trials for each test and the best result was recorded (number of pegs introduced in the holes). The Discrimination Weights Test (DWT, Lafayette Instrument, nº. 16015) (Lafayette Instrument Company, 2004) was used as an indicator of the proprioceptive sensitivity and included three sets. The subject compared the standard weight with one weight at a time (belonging to each set of weights) and verbally stated whether the weight was heavier, lighter, or equal compared to the standard weight. Each of the 11 comparison weights was presented once in a method of constant stimuli to determine the proprioceptive sensitivity. The percentages of correct answers were recorded.

The sample was counterbalanced according to the hand that initiates each test; that is, half of the group started each test with the PH, and the other half started the test with the NPH. Following this procedure, the performance with the contralateral hand was evaluated. This method is used in order to avoid the effect of transfer of learning.

Different evaluators measured all subjects two times (pre- and post-training) and conducted all the physical exercise program sessions. Standardized instructions and explanations of testing procedures were supplied to the subjects in a simple and easy way with respect to the participants from the HC. All procedures were followed as described in the specific batteries and manuals for older adults (Lafayette Instrument Company, 1998, 2002, 2004). The tests were demonstrated and each subject was allowed to perform one training trial on each test before the measured trials.

DATA ANALYSIS

All data were analyzed with the Statistical Package for the Social Sciences (SPSS, version 19.0). They were checked for distribution and the means and standard deviation were calculated. Descriptive statistics and tests for normality (Shapiro-Wilks test) were performed for all outcome variables. To analyze the multimodal exercise program effect, a two-way ANOVA 2x2 (time: from pre- to post-training; gender: males and females) was used for each test according to the performance of the hand (PH, NPH, BH). This analysis was made separately for both groups (EG and the CG) and contexts (HC, RCH, DLC). When ANOVA revealed significant interaction (time x gender), Bonferroni post-hoc tests were performed to determine the differences between the initial and the final values in each group. Statistical significance was set at $p \leq .05$.

RESULTS

Concerning the Modified Baecke Questionnaire data (TABLE 2), and regardless of the exercise program, significant increases from pre- to post-training in the experimental group were found in the residential care home and the daily living center ($p < .001$). The control group maintained the level of daily physical activities from pre- to post-training: residential care home ($p = .148$) and daily living center ($p = .248$).

TABLE 2. Mean and standard deviation for total score of the Modified Baecke Questionnaire. First and second moments for each group: daily living center (DLC) and residential care home (RCH).

	CONTROL GROUP		EXPERIMENTAL GROUP	
Total Score / Moment	DLC	RCH	DLC	RCH
1st	2.51 ± 1.00	1.05 ± 1.13	3.10 ± 1.71	1.66 ± 0.97
2nd	2.36 ± 1.19	0.83 ± 1.15	6.22 ± 3.73	5.68 ± 2.66

Figure 1 presents the mean and standard deviation values of the MMDT for the experimental group (males and females) of the hospital center, the residential care home, and the daily living center, according to the time of assessment (pre and post-training) and the hand (PH, NPH, and BH).

In the experimental group of the hospital center, a significant main effect was found for time with the PH ($F_{1,11}$ = 12.296; p = .005), the NPH ($F_{1,11}$ = 5.057; p = .046), and BH ($F_{1,11}$ = 6.777; p = .025). More specifically, there was a significant improvement in performance from pre- to post-training (PH: from 133.14 ± 19.68s to 111.05 ± 19.50s; NPH: from 146.66 ± 33.10s to 126.89 ± 27.40s; and BH: from 178.47 ± 65.38s to 140.07 ± 56.48s). No other main significant effect or interactions were found. In the residential care home, a significant main effect was found for time with the PH ($F_{1,20}$ = 31.660; p < .001), the NPH ($F_{1,20}$ = 28.593; p < .001), and BH ($F_{1,20}$ = 26.849; p < .001). There was a significant improvement in performance with the PH (from 94.36 ± 13.53s to 83.17 ± 11.84s), the NPH (from 97.94 ± 10.16s to 90.08 ± 11.73s), and BH (from 96.08 ± 20.48s to 81.93 ± 14.83s) from pre- to post-training. No other significant main effect or interactions were found.

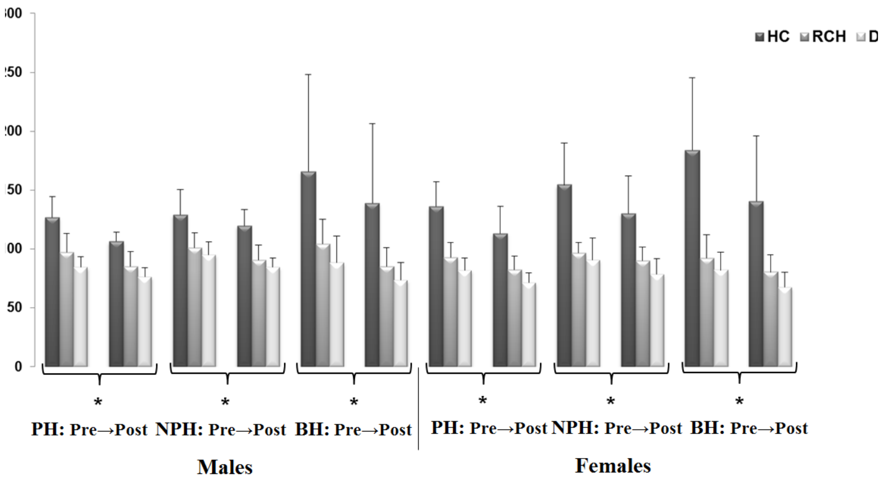

FIGURE 1 – Minnesota Manual Dexterity Test: Means of seconds with the preferred hand (PH), the non-preferred hand (NPH) and both hands (BH) from pre- to post-training in each gender and context: HC (hospital center), RCH (residential care home), and DLC (daily living center), for the experimental group* statistical significance p ≤ 0.05.

In the daily living center, a significant main effect was found for time with the PH ($F_{1,19}$ = 35.640; $p < .001$), the NPH ($F_{1,19}$ = 47.594; $p < .001$), and BH ($F_{1,19}$ = 44.00; $p < .001$). More specifically, there was a significant improvement in performance from pre- to post-training of the PH (from 82.55 ± 9.93s to 72.80 ± 8.35s), the NPH (from 92.02 ± 16.50 s to 80.37 ± 12.09s), and BH (from 84.00 ± 17.59 s to 69.33 ± 13.75s). No other significant main effect or interactions were found. Concerning the control group of the residential care home (older adults with mental health disorders), a significant main effect was found for time with the PH ($F_{1,4}$ = 14.298; p = .019) and the NPH ($F_{1,3}$ = 10.041; p = .051). There was a significant decrease in performance from pre-training (PH: 140.11 ± 31.72s; NPH: 150.33 ± 24.62s) to post-training (PH: 162.41 ± 39.37s; NPH: 175.32 ± 31.11s). No other significant main effect or interactions were found.

In the residential care home, a significant main effect was found for time with the PH ($F_{1,9}$ = 22.711; p = .001), the NPH ($F_{1,9}$ = 11.118; p = .009), and BH ($F_{1,9}$ = 10.893; p = .009). More specifically, there was a significant decrease in performance from pre-training (PH: 92.33 ± 12.84s; NPH: 103.37 ± 16.01s; BH: 88.67 ± 18.58s) to post-training (PH: 100.41 ± 14.16s; NPH: 112.57 ± 14.96s; BH: 95.15 ± 18.29s). No other significant main effect or interactions were found. In the daily living center, a significant main effect was found for time with the NPH ($F_{1,13}$ = 12.105; p = .004) and BH ($F_{1,13}$ = 7.950; p = .014). Specifically, there was a significant decrease in performance from pre-training (NPH: 99.71 ± 14.05s; BH: 89.51 ± 12.97s) to post-training (NPH: 107.88 ± 13.08s; BH: 94.96 ± 14.55s). No other significant main effect or interactions were found.

Figure 2 presents the mean and standard deviation values of the PPT for the experimental group (males and females) of the hospital center, the residential care home, and the daily living center, regarding the time of assessment (pre- and post-training) and the hand (PH, NPH, and BH).

In the experimental group of the hospital center, a significant main effect was found for time with the PH ($F_{1,11}$ = 29.594; $p < .001$), the NPH ($F_{1,11}$ = 8.535; p = .014), and BH ($F_{1,11}$ = 8.303; p = .015). There was a significant improvement in performance from pre-training (PH: 5.76 ± 2.00 pegs; NPH: 5.38 ± 2.39 pegs; BH: 3.15 ± 1.77 pegs) to to post-training (PH: 8.53 ± 1.76 pegs; NPH: 7.61 ± 2.56 pegs; BH: 4.92 ± 1.84 pegs). No other significant main effects or interactions were found. In the residential care home, a significant main effect was found for time with the PH ($F_{1,20}$ = 21.467; $p < .001$), the NPH ($F_{1,20}$ = 18.416; $p < .001$), and BH ($F_{1,20}$ = 11.997; p = .002). There was a significant improvement in performance from pre- to post-training of the PH (from 9.36 ± 2.27 pegs to 10.86 ± 2.31 pegs), the NPH (from 9.13 ± 2.27 pegs to 10.59 ± 2.61 pegs), and BH (from 6.54 ± 1.76 pegs to 7.54 ± 2.17 pegs). No other significant main effect or interactions were found.

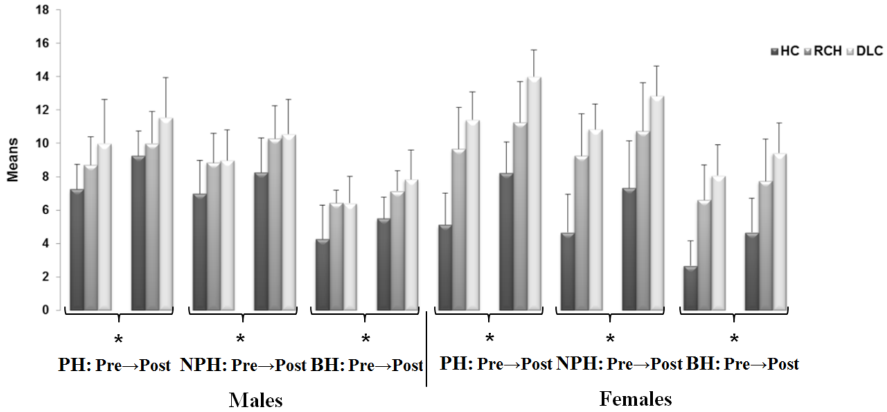

FIGURE 2 – Purdue Pegboard Test: Means of pegs for the preferred hand (PH), the non-preferred hand (NPH), and both hands (BH) from pre- to post-training for each gender and context: HC (hospital center), RCH (residential care home), and DLC (daily living center), for the experimental group * statistical significance p ≤ 0.05.

In the daily living center, a significant main effect was found for time with the PH ($F_{1,19}$ = 88.772; $p < .001$), the NPH ($F_{1,19}$ = 82.465; $p < .001$), and BH ($F_{1,19}$ = 40.646; $p < .001$). More specifically, there was a significant improvement in performance of the PH (from 10.95 2.08 pegs to 13.19 ± 2.18 pegs), the NPH (from 10.23 ± 1.81 pegs to 12.09 ± 2.14 pegs), and BH (from 7.52 ± 1.91 pegs to 8.90 ± 1.92 pegs). A significant main effect was found for gender with the PH ($F_{1,19}$ = 4.829; p = .041) and the NPH ($F_{1,19}$ = 6.899; p = .017). Females presented a better performance (PH: 12.71 ± 1.63 pegs; NPH: 11.85 ± 1.65 pegs) than males (PH: 10.78 ± 2.50 pegs; NPH: 9.78 ± 1.94 pegs). Finally, a significant interaction between time and gender was found for the PH ($F_{1,19}$ = 5.172; p = .035). More precisely, in both genders there was an improvement in performance from pre-training (males: 10.00 ± 2.64 pegs; females: 11.42 ± 1.65 pegs) to post-training (males: 11.57 ± 2.37 pegs; females: 14.00 ± 1.61 pegs) with females presenting a better performance (12.71 ± 1.63 pegs) than males (10.78 ± 2.50 pegs).

In the control group of the residential care home (older adults with mental health disorders), a significant main effect was found for time with the PH ($F_{1,4}$ = 32.000; p = .005) and the NPH ($F_{1,4}$ = 9.800; p = .035). More specifically, there was a significant decrease in performance from pre-training (PH: 6.33 ± 1.36 pegs; NPH: 4.83 ± 1.60 pegs) to post-training (PH: 5.00 ± 1.67 pegs; NPH: 3.66 ± 1.50 pegs). No other significant main effect or interactions were found.

In the daily living center, a significant main effect was found for time with the PH ($F_{1,13}$ = 5.095; p = .042), with a decrease in performance occurring from pre-training (9.73 ± 2.12 pegs) to post-training (9.20 ± 1.69 pegs). A significant interaction between time and gender with BH was found ($F_{1,13}$ = 5.095; p = .042). In both genders, there was a decrease in performance from pre-training (males: 9.75 ± 2.49 pegs; females: 9.71 ± 1.79 pegs) to post-training (males: 9.37 ± 2.06 pegs; females: 9.00 ± 1.29 pegs). No other significant main effects or interactions were found.

Figure 3 presents the mean and standard deviation values of the DWT for the experimental group (males and females) of the hospital center, the residential care home, and the daily living center, according to the time of assessment (pre- and post-training) and the hand (PH and NPH).

In the experimental group of the hospital center, a significant main effect was found for time with the PH ($F_{1,11}$ = 19.003; p = .001) and the NPH ($F_{1,11}$ = 7.277; p = .021). Regarding the PH, there was a significant improvement in performance (from 68.29 ± 4.72 % to 74.81 ± 5.72 % of correct answers) from pre- to post-training. The same occurred with the NPH (from 70.15 ± 8.09 % to 77.84 ± 6.35 % of correct answers). No other significant main effect or interactions were found.

In the residential care home, a significant main effect was found for time with the PH ($F_{1,20}$ = 13.349; p = .002) and the NPH ($F_{1,20}$ = 16.936; p = .001). There was a significant improvement in performance from pre- to post- training of the PH (from 73.68 ± 10.55 % to 82.36 ± 5.88 % of correct answers) and the NPH (from 71.61 ± 9.74 % to 81.67 ± 6.51 % of correct answers). No other significant main effect or interactions were found.

In the daily living center, a significant main effect was also found for time with the PH ($F_{1,19}$ = 23.434; p < .001) and the NPH ($F_{1,19}$ = 58.478; p < .001). There was a significant improvement in performance with the PH (from 72.28 10.72 % to 82.09 4.38 % of correct answers) and the NPH (from 72.43 11.37 % to 82.96 5.28 % of correct answers) from pre- to post- training. With the NPH a significant main effect was found for gender ($F_{1,19}$ = 19.728; p < .001) and for the interaction between time and gender ($F_{1,19}$ = 16.144; p = .001). More particularly, females had a better performance (81.37 ± 6.55 %) than males (70.33 ± 5.74 %) and in both genders there was an improvement in performance from pre-training (males: 60.60 ± 7.62 %; females: 78.34 ± 7.68 % of correct answers) to post-training (males: 80.07 ± 3.85 %; females: 84.40 ± 5.42 % of correct answers).

Concerning the control group of the residential care home (older adults with mental health disorders), a significant main effect was found for time ($F_{1,4}$ = 12.000; p = .026) with the PH. More specifically, there was a significant decrease in performance from pre-training (79.28 ± 2.97 % of correct answers) to post-training (73.22 ± 7.01 % of correct answers). No other significant main effect or interactions were found. In the residential care home, a significant main effect was found for time with the PH ($F_{1,9}$ = 8.523; p = .017) and the NPH ($F_{1,9}$ = 13.877; p = .005). There was a significant decrease in performance from pre-training (PH: 73.82 ± 6.39 % and NPH: 75.19 ± 5.87 % of correct answers) to post-training (PH: 67.48 ± 9.59 % and NPH: 67.48 ± 8.14 % of correct answers). No other significant main effect or interactions were found.

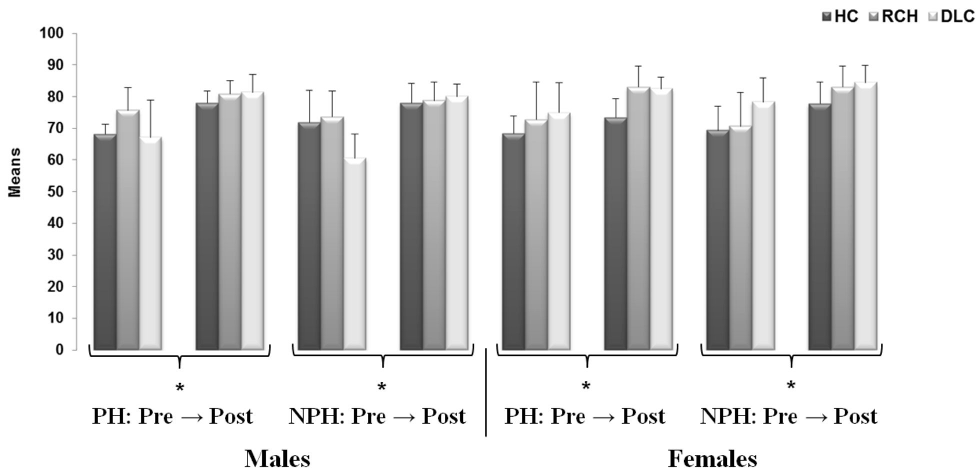

FIGURE 3 – Discrimination Weights Test: Means of percentages (%) with the preferred hand (PH) and the non-preferred hand (NPH) from pre- to post-training in each gender and context: HC (hospital center), RCH (residential care home), and DLC (daily living center), for the experimental group * statistical significance p ≤ 0.05.

In the daily living center, a significant main effect was found for time with the PH ($F_{1,13}$ = 11.898; p = .004) and the NPH ($F_{1,13}$ = 8.701; p = .011). There was a significant decrease in performance from pre-training (PH: 75.75 ± 6.67 %; NPH: 74.13 ± 5.59 % of correct answers) to post-training (PH: 71.50 ± 5.58 %; NPH: 71.71 ± 4.94 % of correct answers). No other significant main effect or interactions were found.

DISCUSSION

The present study aimed to investigate the effects of a multimodal exercise program in the expression of motor fitness and functional motor asymmetry in older adults of both genders from different contexts. Synthesizing our results, the exercise program leads to an improvement of the performance of the limbs in the experimental group. Participants significantly increased their performance from pre- to post-training for the preferred and non-preferred hands. In our study and according to the subjects' manual dexterity (fine and global) the experimental group of all contexts (both genders included) presented a significant improvement from the beginning to the end of the multimodal exercise program. These results are in accordance with the results of Ranganathan, Siemionow, Sahgal, Lui, and Yue (2001) and Botelho and Azevedo (2009) since these authors concluded that older adults who were submitted to an exercise program improved their manual dexterity and visuomotor coordination when compared to their sedentary counterparts.

A key strength of our study was the inclusion of older adults from different contexts. In other words, our sample included more independent and active older adults living in their homes (and attending a daily living center), as well as older adults with less autonomy living in a residential care home and a hospital center both with and without mental health disorders. It is important to point out that adults diagnosed with schizophrenia, included in our study, often presented problems in the domain of motivation and energy control, symptoms that reduce their capacity for healthy nutrition and regular physical exercise (e.g., Vancampfort et al., 2010). Nevertheless, in our study, the older adults belonging to the hospital center showed an improvement in their performance in the final measurement, with regard to the range of abilities developed and assessed.

Our findings are supported by other studies (Carmeli & Liebermann, 2007; Francis & Spidurso, 2000; Taguchi, Higaki, Inoue, Kimura, & Tanaka, 2010), suggesting that through exercise, older adults can gain better motor control, which is of great importance for an independent life, namely for the execution of many of their daily activities requiring manual skills (Carmeli & Liebermann, 2007; Francis & Spidurso, 2000). This hints that motor strategies and motor control of movements can be preserved using a multimodal exercise program where the abilities that sustain these movements and actions are systematically trained. Governments should be aware of the importance of developing multimodal exercise programs to assist sedentary older adults and to promote strategies allowing subjects to achieve old age with better health and function. In our opinion, finding ways to prevent or ameliorate age-related cognitive decline is a public health imperative, with potential benefits not just in terms of lessening aged care costs, but also in the enhancement of the well-being of a growing segment of society.

Through the data of the daily living center (e.g., Purdue Pegboard Test) our research supports some studies that suggest the superiority of females in manual dexterity (e.g., Amirjani, Ashworth, Gordon, Edwards, & Chan, 2007; Sarafraz & Vahedi, 2008). However, this is still a topic of controversy where other studies using other evaluation methods (e.g., the Pursuit Rotor Test) confirm the superiority of males in the same ability (e.g., Cãmina, Arce, Real, Cancela, & Romo, 2001). It is known that with aging there is a decrease in manual dexterity (e.g., Carment et al., 2018; Carmeli & Liebermann, 2007), as observed in our control group whose older adults diminished their performance from pre- to post-training. Emphasis is placed on several studies like ours, suggesting that the decline of manual dexterity can be fought with the practice of regular exercise (e.g., Botelho & Azevedo, 2009).

Beyond that, the older adults from all contexts improved their proprioceptive sensitivity from pre- to post-training. Probably, the reasons for these improvements are related to a more accurate muscle response to the movements and tasks required for the performance of everyday life activities. A better proprioceptive sensitivity also provides a higher conscientiousness of the body in the tridimensional space, allowing better information processing with respect to time and space parameters that provide a more independent life (Carmeli & Liebermann, 2007). In general, these studies refer to the belief that the functioning of the manual proprioceptive sensibility and manual dexterity are essential for the accurate control in the manipulation of small objects and for the completion of many daily activities. With aging, the muscle strength, the sensibility, the touch-pressure threshold, the neuromuscular coordination, the vision, the hearing, the nerve conduction velocity, the skin receptors, the sensory perception, and the central processing change (Carmeli, Patish, & Coleman, 2003; Huy, 2019). These changes affect the hand function (Carmeli & Liebermann, 2007; Carmeli, Patish, & Coleman, 2003), but according to our results and others previously mentioned, exercise can delay the decline of these parameters or even promote their development.

In our study, concerning the variable gender and the interaction between time and gender in the experimental group, we verified an improvement in the older adults' proprioceptive sensitivity from the daily living center, with females having obtained a better performance than males with the NPH from pre- to post-training. In this context, Ranganathan et al. (2001) state that a training program that gives adequate stimuli to the sensory-motor system will possibly diminish the weakness related to age in the manual function. In this way, the exercise programs should explore exercises that emphasize the kinesthetic discrimination in order to improve the sensorial perception and the manual dexterity (Carment et al., 2018; Elfant, 1977). Considering this, the exercises of our one-year multimodal program were aimed primarily at promoting the development of hand-eye and foot-eye coordination and proprioceptive sensitivity.

To what concerns the proprioceptive sensitivity, the advantage of females over males (NPH) observed in our study can be a consequence of the type of activities traditionally performed by women, such as cooking, washing, and ironing. These activities, due to their nature, can afford a more proprioceptive sensitivity and dexterity proficiency in the use of the females' hands (e.g., Amirjani et al., 2007). Particularly, considering the NPH, females usually incorporate this hand into their routine in activities that recruit the use of the NPH in movements of support and fixation or in the performance of manual arts. These activities are performed less frequently among men who are better in the normal use of the PH to perform other activities related to manual skills, such as manual strength (Rand & Eng, 2010). As the proprioceptive sensitivity is a motor skill largely related to the implementation of tasks that require spatial orientation of the limb, perception, and precision, the specific activities of daily living could also favor females in somatosensory processing. On the other hand, in the Discrimination Weights Test, in all contexts the older adults of the control group showed a significant decline of their proprioceptive sensitivity. As it was concluded in the study of Takeshima, William, Ueya, and Tanaka (2000), the digital sensibility declines with the advancement of age.

Exercise seems to improve mental health and well-being, reduce depression and anxiety, and enhance cognitive functioning (e.g., Seino et al., 2019; Spirduso, 2009). The mental health disorder that characterizes a part of our sample is adults diagnosed with schizophrenia, whose symptoms include not only the positive psychotic, disorganized thought and speech, delusions, hallucinations and other changes in perception, but also the negative symptoms, such as lack of motivation and social withdrawal (Cicero, Jonas, Li, Perlman, & Kotov, 2019; Sewell, Skosnik, Garcia-Sosa, Ranganathan, & D'Souza, 2010). The subjects of the experimental group benefited from the program, which helps outline strategies for action, either to improve their motor condition or to improve their quality of life, including their socio-affective relations. However, we emphasize that it is possible for these older adults to participate in these exercise programs. Researchers found that midlife exercises may reduce the risk of dementia decades later (e.g., Andel et al., 2008; Annear, Lucas, Wilkinson, & Shimizu, 2019), suggesting that exercise interventions should be explored as a potential strategy for delaying disease onset. They also found that light exercise, such as gardening or walking, and regular exercise involving sports were associated with reduced odds of dementia. It was verified in our study that the older adults of the control group decreased their performance in all the studied abilities. This suggests that inactivity affects functionality, mobility, and health, depriving older adults of an autonomous and healthy life and harming their quality of life (Carmeli & Liebermann, 2007; Spirduso, Francis, & MacRae, 2005; Vasconcelos, Cardozo, Lucchetti, & Lucchetti, 2016).

The major limitation of our study was finding a sufficient number of older adults with mental health disorders who could perform a one-year program of regular exercise. A key strength of our study is that, to our knowledge, there is not much existing information and systematic research on this subject. Therefore, we believe that our results can contribute to a better understanding of the effect of exercise on different abilities of older males and females from different contexts. Although the contexts of our study were not compared, we collected data and analyzed and discussed results coming from three different human realities in the same investigation, whereas the majority of studies conducted in this domain only deal with one context.

In summary, we partly confirmed our previous hypothesis, that our program of multimodal exercise had significant effects on older adults with and without mental health disorders from different contexts. We emphasize that we should give special attention to multicomponent exercise programs and apply them to older adults with or without mental health disorders since they improve motor fitness, which is important for an independent lifestyle and thus for an older adult's quality of life. In the domain of this investigation, we suggest a follow-up study to investigate the effect of inactivity after six months or one year.

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