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120 min/week of neuromotor multicomponent training are enough to improve executive function and functional fitness in older women

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ABSTRACT

Purpose: The study aimed at comparing the effects of a neuromotor multicomponent training program (MCTP) on executive function, functional fitness, blood pressure, body composition and health-related quality of life (HRQOL), compared with a concurrent strength and endurance exercise training program (CONTROL-EXE) and a cognitive training program (CONTROL-COG).
Methods: 56 older women (73 ± 6 years) completed the 30-weeks intervention. The three groups attended two 60-min sessions per week and they were assessed before and after the intervention.
Results: MCTP showed a moderate improvement in Stroop C condition (28 ± 7 vs 32 ± 8 correct items; $p = 0.001$; d = 0.53) and Stroop interference score (−7.4 ± 7.3 vs −3.7 ± 6.1; $p = 0.035$; d = 0.55), while no changes were observed among control groups. MCTP showed a small to moderate improvement in Timed Up and Go test (TUGT) (5.85 ± 0.58 vs 5.46 ± 0.56 s; $p < 0.001$; d = 0.71) and Chair-Stand test (CST) (18 ± 4 vs 19 ± 4 repetitions; p < 0.001; d = 0.47); while CONTROL-EXE only improved moderately at TUGT (7.02 ± 1.1 vs 6.44 ± 0.91 s; $p = 0.005$; d = 0.59) and CONTROL-COG showed a moderate to small worsening in TUGT, CST and handgrip strength. Additionally, MCTP enhanced body composition and HRQOL. Lastly, both exercise groups showed lowered blood pressure values.
Conclusions: Our results suggest that a neuromotor MCTP could be considered as a highly suitable training to enhance executive function, functional fitness, HRQOL and body composition in older women.

1. Introduction

Virtually every country in the world is experiencing a growth in the number and proportion of older persons in their population, due to an increase in life expectancy and a decline in mortality and fertility rates. According to last United Nations prospects, by 2050, one in six people in the world will be over age 65 and the number of persons aged 80 or over is projected to triple between 2019 and 2050 (UN, 2020). This population aging is one of humanity's greatest triumphs, but it also confronts societies with enormous social and medical challenges (Lee et al., 2020). In such a situation, there is an overwhelming evidence that regular physical exercise constitutes a cornerstone to increase life expectancy in good health (Fiuza-Luces et al., 2013; Kasiakogias and Sharma, 2020).

Among the types of exercise training most recommended for elderly people, multicomponent training programs (MTCP) have attracted the attention from the scientific community in the last few years (Bouaziz et al., 2016; Saez de Asteasu et al., 2017). Those training regimes usually include strength, endurance and balance tasks and have been demonstrated to improve older adults' functional fitness and health-related quality of life (HRQOL) (Bouaziz et al., 2016; Falck et al., 2019). Functional fitness refers to physical function that enables older adults to independently and safely perform activities of daily living (Rikli and Jones, 2012). It is also considered essential to delay the onset of frailty and dependence (Peterson et al., 2009).

Moreover, it has been suggested that MCTP, as compared with training programs based on endurance or resistance exercises in isolation, may have the most positive effects on cognitive function in this population (Kelly et al., 2014; Saez de Asteasu et al., 2017). However,

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irrespectively of the physical domains targeted in the training program, the complexity of the cognitive and coordinative demands of training tasks might contribute to its cognitive outcomes; exercises involving low complexity demands (i.e., repetitive tasks performed under much controlled conditions) are known to provoke a less pronounced effect on high-domain cognitive abilities (Voelcker-Rehage and Niemann, 2013). Executive function encompasses those abilities, by which performance is optimized in situations requiring the simultaneous operation of several cognitive processes. Executive functions thus control the planning, sequencing and execution of complex goal-directed activities (Spirduso et al., 2008).

On the other hand, MCTP in previous studies have been usually performed on a thrice-weekly basis (Bouaziz et al., 2016; Kelly et al., 2014; Saez de Asteasu et al., 2017), following common international health guidelines that generally recommend at least 150 min per week of moderate to vigorous physical activity (Warburton and Bredin, 2016). However, lack of time remains one of the most commonly cited barriers to regular exercise participation among older adults (Garmendia et al., 2013) and high time commitment programs may act against adherence to exercise training in this population (Warburton and Bredin, 2016).

Therefore, the main purpose of our study was to assess the effects of a 30-week, 60 min twice-weekly neuromotor (i.e., encompassing a high degree of cognitive and coordinative load) MCTP on executive function and functional fitness, in comparison with a concurrent strength and endurance training program and a cognitive training program. As a secondary aim, we wanted to know the effects of the abovementioned program on blood pressure, body composition and HRQOL. We hypothesized that a neuromotor MCTP would promote comparable executive function gains as a cognitive training program, and greater executive function gains than a concurrent strength and endurance training program. At the same time, we thought that both the neuromotor MCTP and the concurrent strength and endurance training program may lead to an improvement in functional fitness.

2. Material and methods

2.1. Participants

One hundred and four community-dwelling older adults were recruited from a public senior care centre (CEAM El Cabañal, Valencia, Spain). Inclusion criteria were: a) being at least 65 years old; b) living at home; c) close geographical proximity to training facilities; d) not presenting any circumstance that could alter or advise against undergoing physical testing (i.e., chronic or acute diseases, medication); e) not presenting a cognitive impairment, assessed by the Mini-Mental State Examination (MMSE) and using a score higher than 24 as cut-off threshold (Folstein et al., 1975); f) not presenting any medical contraindication to engage in a moderate intensity physical training (only for EXP and CTR-ET). The last three criteria were judged by the medical staff of the care facility. Participants were informed that their participation in the study was voluntary and confidential. They gave their informed written consent to participate in compliance with the ethical standards provided in the Declaration of Helsinki and the study was approved by the research ethics committee of the University of Valencia (H1363126067752). A detailed feedback of their performance and training progress was delivered to each participant at the end of the study.

2.2. Outcome measurements

Outcome measurements were assessed on two non-consecutive days, within two weeks before and after the training period for all participants. On the first evaluation day, participants answered to SF-12v2 questionnaire and underwent physical testing. On the second evaluation day, blood pressure was measured, participants were heighted and weighted and performed the Stroop test. Investigators were blinded from baseline results during post-intervention testing and the same investigators performed each test at baseline and post-intervention to ensure consistency. Each subject performed the tests at the same time of the day and in the same order throughout the study.

Executive function was assessed utilizing the Stroop test (Golden, 1994), which provides an evaluation of selective attention and inhibitory control and includes 3 time-limited (45-s) subtests (Golden, 1978). Each subtest includes 100 stimuli (5 columns by 20 rows) printed on a 29.7 × 21 cm sheet of paper. In the first condition (A, reading), the participant has to read a list of words printed in black ink that name colors ("red", "green" and "blue"). In the second condition (B, naming), the participant is asked to name the color of coloured-X's. In the third condition (C, response inhibition), the participant has to name the color of the ink in which the words are written, ignoring the automatic reading of the word's incongruent meaning (i.e., the word "blue" printed in red ink). The outcomes retained for statistical analysis were the "C" condition score (Stroop_C) and the overall interference score (Stroop _I), calculated via the formula Stroop_I = Stroop _C − (Stroop _A * Stroop _B)/(Stroop _A + Stroop _B). Thus, the higher the Stroop _I, the lesser the susceptibility to interference (Golden, 1994).

Dynamic balance and mobility was assessed using the 8-ft Timed Up and Go Test (TUGT) which measures the time taken by a participant to stand up from a standard chair without leaning forward from the back support of the chair, walk a distance of 2.44 m, turn around a cone and walk back to the chair and sit down (Rikli and Jones, 2012). Each participant was given two attempts and a high-speed camera recording (210 Hz, Casio HS EX-FH100) was employed to time the best performance (in seconds). Lower limb physical performance was evaluated employing the Chair Stand Test (CST), where participants rise to a full standing position and then return to a seated position, with arms folded across their body, as many times as possible within the 30-s time limit (Rikli and Jones, 2012). The number of repetitions completed within the time limit was recorded. Upper limb strength was measured using a handheld isometric dynamometer (Smedley; TTM, Tokio, Japan). Participants were instructed to stand with their heels, back and elbows against a wall and hold the dynamometer in their dominant hand with a 180° angle at the elbow and a neutral wrist. Subjects were asked to squeeze the dynamometer for 5 s and the test was performed twice, with 30 s of rest in between attempts. Strong verbal encouragement was given during both attempts and the highest value was retained for statistical analysis.

As secondary outcomes, body composition, blood pressure and HRQOL were assessed. Height and weight were measured with the aid of a stadiometer (SECA 206; Seca Corporation, Hamburg, Germany) and a bioelectrical impedance weight scale (BC-601; Tanita, Tokio, Japan). Body mass index (BMI), fat mass index (ratio between fat mass and height squared) and skeletal muscle index (ratio between lean mass and height squared) were retained for statistical analysis. Measurements were performed in a fasted state (>6 h) with the participants in light clothing, following the manufacturer's guidelines. On the other hand, after 5 min of sitting at rest, systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured on both arms using a manual sphygmomanometer (Minimus III; Riester, Jungingen, Alemania). The mean of the two readings was used as the value for SBP and DBP. All measures were taken using an appropriate-sized cuff during screening, according to the European Society of Hypertension (Mancia et al., 2007). Lastly, HRQOL was assessed using the Medical Outcome Survey SF-12v2 questionnaire (Resnick and Nahm, 2001). Global score and mental and physical components scores were calculated using a 0 to 100 scale; the higher the punctuation, the greater the health perception (Ware et al., 2009).

2.3. Intervention

The study was designed as a non-randomized intervention. Participants were assigned to the neuromotor MCTP group (EXP) or one of the two control groups (cognitive training group, CONTROL-COG; and exercise control group, CONTROL-EXE) based on the schedule inside the care facility and the daily routine of the participants. The three groups attended two 60-min sessions per week for 30 weeks. An attendance rate higher than 70% was mandatory to be considered in the final sample of the study (Garmendia et al., 2013). EXP was considered as the main intervention, whereas CONTROL-EXE served as an active control (EXP and CONTROL-EXE performed the same weekly amount of exercise) and CONTROL-COG served as a control for isolated cognitive training. At the same time, this experimental approach enabled us to account for the social benefits of group-based activities among older adults. Fig. 1 shows the flow of participants through the investigation. Given the low number of men that completed the intervention (7 out of 63), they were finally excluded from the analysis to avoid possible interferences from sex differences regarding training response.

The EXP group followed a multicomponent neuromotor training which involved combinations of motor learning, endurance and strength exercises based on a progressive increase in motor control demands. Moreover, specific cognitive challenges were integrated into the physical training to stimulate executive function (inhibition, working memory and cognitive flexibility) and spatial perception, given that those two cognitive functions are known to be especially affected by aging (Spirduso et al., 2008). This training program has been registered as an intellectual property under the name of EFAM-UV® program (Blasco-Lafarga et al., 2016).

EFAM-UV® training program was periodized into 3 specific training cycles: conditioning phase (weeks 1–10), neuromuscular phase (weeks 11–21) and endurance phase (weeks 22–30). Training sessions began with motor learning exercises followed by endurance tasks and finished with strength exercises (Wang et al., 2011). The duration of each block varied as a function of the training cycle (i.e., motor learning exercises prevailed in the conditioning phase whereas strength and endurance

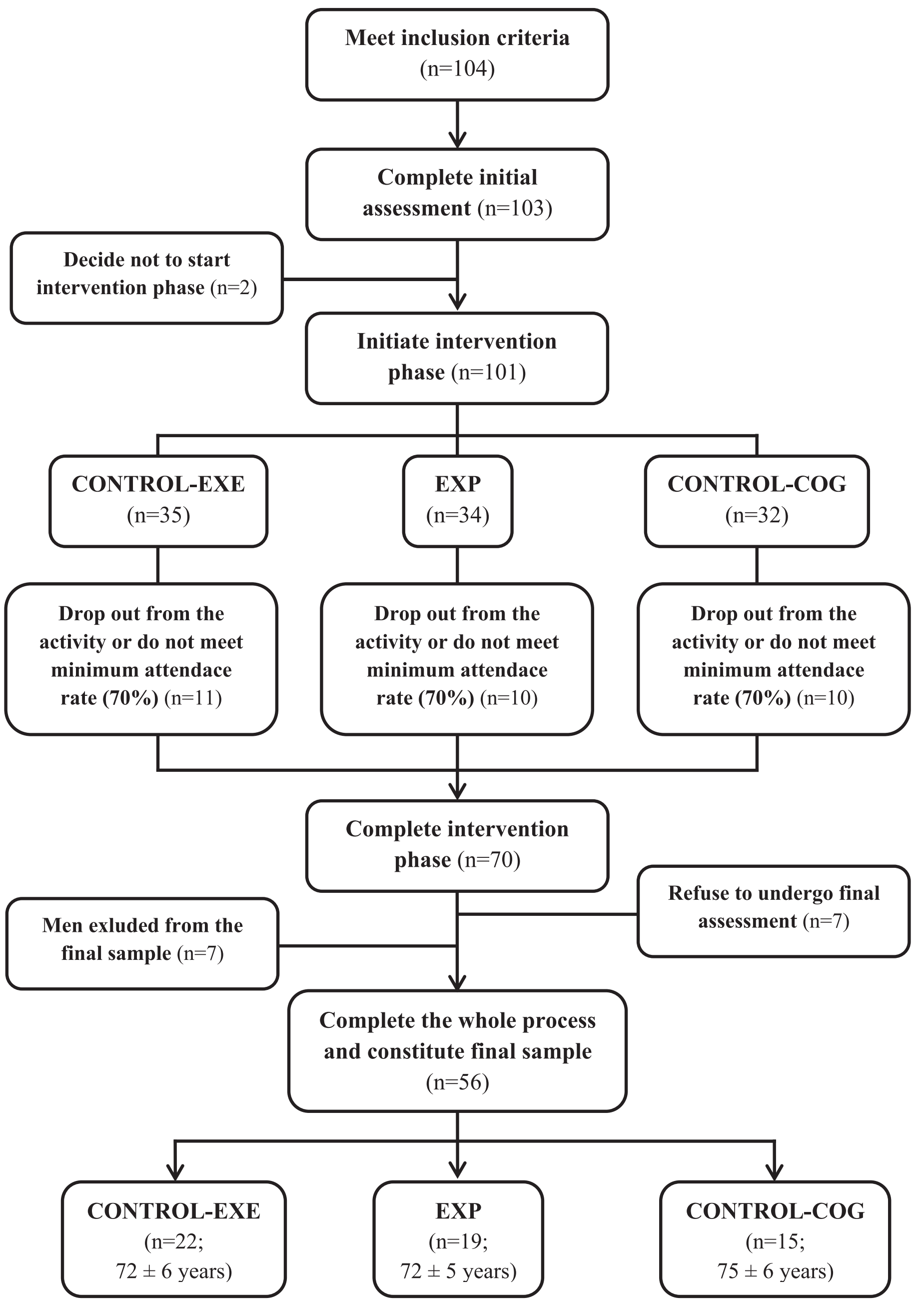

Fig. 1. Flow of participants through the investigation.

tasks were prevalent in the second and third phase respectively). A maximum participant-to-instructor ratio of 8 was fixed to minimize any training-related risk of falling and make it possible to adjust and individualize exercise progression both in the EXP and the CONTROL-EXE groups.

Motor learning exercises consisted of eye-hand coordination exercises with swiss and foam balls. Gait training consisted of walking while carrying out changes in step length, speed and direction, as well as movement sequences and interlimb coordination tasks. Difficulty was also increased by walking while avoiding (i.e., turning around) and/or negotiating (i.e., climbing over) obstacles such as steps or hurdles. Gait training was progressively mixed with rhythmic stepping and dual-task switch exercises. Endurance training consisted of fast walking tasks using intervallic approaches and implemented when appropriate in a ludic games format. Cognitive engagement was emphasized in this block using movement rules and providing an enriched environment to impact on working memory and spatial perception. Strength exercises targeted all major muscle groups and consisted of dumbbell raises performed while seated on swiss balls and standing exercises with elastic tubes performed on pairs. In this intervention, sets and repetitions evolved from 1 to 2 sets of 12–15 repetitions (1st phase) to 3–4 sets of 8–10 repetitions (2nd phase) and 2–3 sets of 8–10 repetitions (3rd phase). Weight of dumbbells as well as thickness of elastic tubes were gradually increased as to maintain a rate of perceived exertion (RPE) of somewhat hard to hard (i.e., a RPE of 6–8 points using the OMNI-RES of 0–10) (Gearhart Jr. et al., 2009). Tasks were designed to enable also an integrated progression in coordination (i.e., interlimb coordination, contralateral coordination) and postural control (i.e., changes in the base of support, alteration of visual and vestibular inputs) requirements to match each participant's ability and to be continuously challenging but safe.

Concurrent training in the CONTROL-EXE also include motor learning, endurance and strength exercises. CONTROL-EXE performed a progressive increase in quantitative load parameters (i.e., walking speed, exercise: rest ratio, weight of dumbbells, thickness of elastic tubes), but not in qualitative load parameters (coordination, balance, cognitive engagement). This was the distinctive feature between the two exercise programs. CONTROL-COG performed paper-and-pencil brain exercises aimed at stimulating medium and long-term memory. Intensity progression in both control groups was based on subjective perceived exertion as in the EXP group.

2.4. Statistical analysis

Statistical analyses were carried out using the Statistical Package for the Social Sciences software (IBM SPSS Statistics for Windows, version 22.0, IBM Corp., Armonk, NY). Normal distribution of the variables was verified through the Kolmogorov-Smirnov test ($p < 0.05$). Possible differences between groups before the intervention were assessed using a multivariate ANOVA. Afterwards, a repeated-measures MANCOVA was conducted for each primary and secondary outcome, using its baseline score as a covariate to account for possible baseline differences between groups. 'Time' (pre-intervention vs post-intervention) was considered as within-factor and 'Group' (EXP, CONTROL-EXE and CONTROL-COG) as between-factor. Pairwise comparisons were performed using Bonferroni's test.

On the other hand, bivariate Pearson correlations were used to explore possible interrelationships between changes in the studied outcomes (Falck et al., 2019). To that purpose, post-intervention Stroop_I was expressed as the absolute difference from pre-intervention value; while for the remaining variables, post-intervention data for each subject was related to the individual baseline level to calculate delta scores (Δ): Δ (percentage change) = (post-race value – pre-race value)/pre-race value. The meaningfulness of the outcomes was estimated through the partial estimated effect size (η2 partial) for ANOVA and Cohen's d effect size for pairwise comparisons. Small, medium and large effects were considered when η2 partial was lower than 0.06, between 0.06 and 0.14, and greater than 0.14 respectively. Threshold values for Cohen's D were lower than 0.5, between 0.5 and 0.8, and greater than 0.8. Likewise, correlations >0.5 were considered strong, 0.3–0.5, moderate and <0.3, small. The significance level was set at p-value <0.05 and data are presented as means and standard deviations (±SD).

3. Results

Values of Stroop test and physical tests at pre and post-intervention are presented in Table 1. At baseline, no differences between groups were identified in Stroop_C, Stroop_I and handgrip strength; however, EXP displayed better values than CONTROL-EXE and CONTROL-COG in TUGT and CST. Repeated measures ANOVA showed a significant effect for 'Time' factor on Stroop_C [F(1,52) = 15.70; $p < 0.001$; η2 partial = 0.24], Stroop_I [F(1,52) = 3.62; $p = 0.043$; η2 partial = 0.07], TUGT [F(1,52) = 17.28; p < 0.001; η2 partial = 0.25] and CST [F(1,52) = 173.41; $p = 0.001$; η2 partial = 0.21]. 'Time x Group' interaction effects were identified on STR_C [F(2,52) = 3.71; $p = 0.032$; η2 partial = 0.13], TUGT [F(2,52) = 10.25; $p < 0.001$; η2 partial = 0.29] and CST [F(2,52) = 21.72; $p < 0.001$; η2 partial = 0.46]. Further Bonferroni adjusted pairwise comparisons showed that EXP improved moderately Stroop_C (p = 0.001; d = 0.53) and Stroop_I performance ($p = 0.035$; d = 0.55), while no changes were observed among control groups. Regarding physical outcomes, EXP showed a small to moderate improvement from pre to post-training in TUGT (p < 0.001; d = 0.71) and CST (p < 0.001; d = 0.47); CONTROL-EXE improved moderately at TUGT ($p = 0.005$; d = 0.59); and CONTROL-COG showed a small to moderate worsening in TUGT ($p = 0.008$; d = 0.07), CST (p < 0.001; d = 0.91) and handgrip strength (p = 0.005; d = 0.50).

Values of body composition, blood pressure and HRQOL variables at pre and post-intervention are presented in Table 2. At baseline, the only difference between groups was identified in SF-12 global score, where EXP displayed better values than CONTROL-EXE. Repeated measures ANOVA showed a significant effect for 'Time' factor on SBP [F(1,52) = 19.13; $p < 0.001$; η2 partial = 0.28], DBP [F(1,52) = 31.38; p < 0.001; η2 partial = 0.39], BMI [F(1,52) = 8.63; p = 0.005; η2 partial = 0.15], skeletal muscle index [F(1,52) = 4.94; $p = 0.031$; η2 partial = 0.09], SF-12 global score [F(1,52) = 5.48; $p = 0.023$; η2 partial = 0.10], SF-12

Table 1
Values of Stroop test and physical tests at pre and post-intervention (mean ± SD).

	Experimental group		Cognitive control group		Exercise control group	
	Pre	Post	Pre	Post	Pre	Post
Age (years)	72 ± 5		75 ± 6		72 ± 6	
MMSE score (0–30)	29 ± 1		29 ± 1		29 ± 1	
Stroop_C (correct items)	28 ± 7	32 ± 8[a c]	26 ± 6	26 ± 7	25 ± 10	26 ± 8
Stroop _I	−7.4 ± 7.3	−3.7 ± 6.1[a]	−4.1 ± 5.4	−4.5 ± 4.7	−2.9 ± 7.6	−3.9 ± 6.7
TUGT (s)	5.85 ± 0.58[b c]	5.46 ± 0.56[a b]	8.16 ± 1.42	8.25 ± 1.43[a]	7.02 ± 1.1	6.44 ± 0.91[a b]
CST (repetitions)	18 ± 4[b c]	19 ± 4[a b]	14 ± 3	12 ± 3[a]	14 ± 3	16 ± 3[b]
Handgrip strength (kg)	24.1 ± 4.4	23.4 ± 4.9	22.4 ± 3.5	20.8 ± 3.4[a]	23.5 ± 4	22.8 ± 3.8

Abbreviations: MMSE, Mini-Mental State Examination; Stroop_C, Stroop "C" condition score; Stroop _I, Stroop test interference score; TUGT, 8-foot Timed Up and Go Test; CST, 30-s Chair Stand Test.

[a] Significantly different from pre-intervention condition ($p < 0.05$).
[b] Significantly different from cognitive control group (p < 0.05).
[c] Significantly different from exercise control group (p < 0.05).

Table 2
Values of body composition, blood pressure and HRQOL variables at pre and post-intervention (mean ± SD).

	Experimental group		Cognitive control group		Exercise control group	
	Pre	Post	Pre	Post	Pre	Post
BMI (kg/m^2)	27 ± 2.9	26.2 ± 2.6[a b]	30.4 ± 4.2	30.8 ± 3.8	29.9 ± 5.3	29.7 ± 4.9
Fat Mass Index (kg/m^2)	10.6 ± 2.2	9.9 ± 2.4[a b]	11.8 ± 2.5	12.1 ± 2.7	12.8 ± 3.6	12.5 ± 3.3
Skeletal Muscle Index (kg/m^2)	17.2 ± 1.6	16.8 ± 1.7	17.7 ± 2.6	17.4 ± 2.4	17.4 ± 2.2	17.5 ± 2.1
SBP (mm Hg)	129 ± 13	123 ± 10[a]	124 ± 10	124 ± 8	135 ± 16	125 ± 15[a]
DBP (mm Hg)	69 ± 9	68 ± 7	68 ± 6	69 ± 7	75 ± 8	66 ± 6[a]
SF-12 Global score	77 ± 10[c]	82 ± 12[a b]	72 ± 19	62 ± 23[a]	63 ± 17	68 ± 17[b]
SF-12 Physical component	75 ± 13	82 ± 14[a b]	70 ± 19	56 ± 24[a]	61 ± 19	66 ± 21[b]
SF-12 Mental component	71 ± 11	76 ± 12[a]	66 ± 20	62 ± 23	59 ± 19	62 ± 17

Abbreviations: BMI, body mass index; Fat Mass Index, ratio between fat mass and height squared; Skeletal Muscle Index, ratio between lean mass and height squared; SBP, systolic blood pressure; DBP, dyastolic blood pressure.
[a] Significantly different from pre-intervention condition ($p < 0.05$).
[b] Significantly different from cognitive control group ($p < 0.05$).
[c] Significantly different from exercise control group ($p < 0.05$).

physical component [$F(1,52) = 5.11$; $p = 0.028$; η2 partial = 0.09] and SF-12 mental component [$F(1,52) = 8.68$; $p = 0.005$; η2 partial = 0.15]. 'Time x Group' interaction effects were identified on BMI [$F(2,52) = 5.91$; $p = 0.005$; η2 partial = 0.19], fat mass index [$F(2,52) = 3.40$; $p = 0.041$; η2 partial = 0.12], SF-12 global score [$F(2,52) = 6.69$; $p = 0.003$; η2 partial = 0.21] and SF-12 physical component [$F(2,52) = 8.89$; $p < 0.001$; η2 partial = 0.26]. Further Bonferroni adjusted pairwise comparisons showed that EXP showed a moderate reduction in SBP from pre to post-training ($p = 0.009$; d = 0.50) and CONTROL-EXE lowered moderately to largely SBP ($p = 0.002$; d = 0.66) and DBP ($p < 0.001$; d = 1.30). In addition, EXP showed a small reduction in BMI ($p = 0.001$; d = 0.29) and fat mass index ($p = 0.008$; d = 0.34). Lastly, EXP improved lightly to moderately SF-12 global score ($p = 0.023$, d = 0.51), SF-12 physical component ($p = 0.011$, d = 0.58) and SF-12 mental component ($p = 0.025$, d = 0.44); while CONTROL-COG showed a moderate worsening in SF-12 global score ($p = 0.011$; d = 0.50) and SF12 physical component ($p = 0.002$; d = 0.71).

Correlational analysis between delta changes in the assessed outcomes showed that Δ Stroop_C was moderately associated with Δ CST ($r = 0.32$, $p = 0.020$); while Δ Stroop_I was moderately correlated with Δ CST ($r = 0.35$, $p = 0.012$) (Fig. 2, panel A), Δ BM ($r = -0.35$, $p = 0.011$) (Fig. 2, panel B), and Δ fat mass index ($r = -0.35$, $p = 0.011$). Δ TUGT appeared moderately associated with Δ SF-12 global score ($r = -0.43$, $p = 0.001$) (Fig. 2, panel C) and Δ SF-12 physical component ($r = -0.46$, $p = 0.001$) (Fig. 2, panel D), and kept a light relationship with Δ SF-12 mental component ($r = -0.26$, $p = 0.044$). Δ CST was lightly correlated with SF-12 physical component ($r = 0.28$, $p = 0.043$). Lastly, Δ Handgrip strength showed a moderate relationship with SF-12 physical component ($r = 0.33$, $p = 0.017$) and Δ SF-12 global score ($r = 0.31$, $p = 0.029$).

4. Discussion

Our results showed that the neuromotor MCTP was the only intervention that led to an enhancement in executive function, HRQOL and body composition. Our first hypothesis was therefore partially confirmed, because CONTROL-COG failed to show an improvement in executive function following the intervention. Regarding physical outcomes, EXP improved lower-limb dynamic balance and physical performance, while CONTROL-EXE only improved lower-limb dynamic balance and CONTROL-COG showed a worsening in upper-limb strength and lower-limb dynamic balance and physical performance following the intervention. Accordingly, our second hypothesis was also confirmed, although functional fitness improvement was broader in the EXP group as compared with the CONTROL-EXE group. Moreover, those beneficial adaptations were achieved with only two 60-min training sessions a week, an exercise time commitment even lower than the one commonly advocated by public health guidelines.

Cognitive decline is a plausible consequence of the aging process and it is associated with an increased risk of dementia and adverse health outcomes such as functional dependence and disability (Spirduso et al., 2008), thus placing a substantial economic burden on health care systems and society (UN, 2020). Consequently, interventions able to improve cognitive abilities, especially those that are usually more affected in older adults such as executive function, are essential to control the exponential growth of dementia and related disorders in this age group (Falck et al., 2019). Our results corroborate that multicomponent exercise training conducted in an enriched environment (i.e., enabling decision-making opportunities) that imposes a high cognitive load (i.e., EFAM-UV® program) could be considered a highly suitable training to meet this purpose, as compared with less cognitively-taxing traditional exercise training programs (Falbo et al., 2016; Vaughan et al., 2014). The reasoning behind could be that in the EFAM-UV® program participants are driven to provide adjusted movements in response to changing stimuli (i.e., dual-task switch exercises, usage of movement rules), while traditional exercise training programs targeted to elderly people usually employ more repetitive single tasks performed under much controlled conditions. Additionally, exercise training involving higher coordinative and postural control demands seems to specifically strengthen parts of the neural networks that are particularly impaired during aging, leading to more efficient motor responses and more effective processing and integration of visuo-spatial information (Voelcker-Rehage and Niemann, 2013). On the other hand, the relationship between pre to post-intervention changes in executive function and lower-limb physical performance is in line with previous studies suggesting that exercise-induced enhancement of physical and cognitive function may be linked because of shared biological pathways and neural substrates targeted by exercise training (Bolandzadeh et al., 2015; Falck et al., 2019; Hsu et al., 2017), and reinforces the notion that exercise training in the elderly should be taxing enough not only to achieve physical benefits but also to achieve cognitive benefits (Saucedo Marquez et al., 2015).

Contrary to our expectations, CONTROL-COG failed to show an improvement in the Stroop test. Previous studies comparing physical and cognitive training interventions have shown either similar results (Barnes et al., 2013; Klusmann et al., 2010) or more favourable outcomes following cognitive training (i.e., as compared with physical training) (Shatil, 2013). On one hand, it could be that paper-and-pencil brain exercises performed by CONTROL-COG were not challenging and novel enough to promote an improvement in fluid cognitive abilities (Klusmann et al., 2010). On the other hand, it has been suggested that cognitive benefits from cognitive training are domain specific and transfer effects are limited (Spirduso et al., 2008). This could explain the absence of an executive function improvement in CONTROL-COG after an intervention aimed at enhancing crystallized cognitive abilities (i.e., medium and long-term memory). Collectively, our results suggest that well-rounded and supervised exercise interventions are relevant to improve older adults' executive function, even when compared to a memory-focused cognitive training. These findings extend beneficial effects on gait parameters, body composition and physical fitness showed in previous interventions using EFAM-UV® training program (Blasco-Lafarga et al., 2020; Roldan et al., 2019; Sanchis-Sanchis et al., 2020). Nevertheless, further studies including both a broader cognitive assessment and an executive function-focused cognitive training are warranted to reinforce the abovementioned assumption.

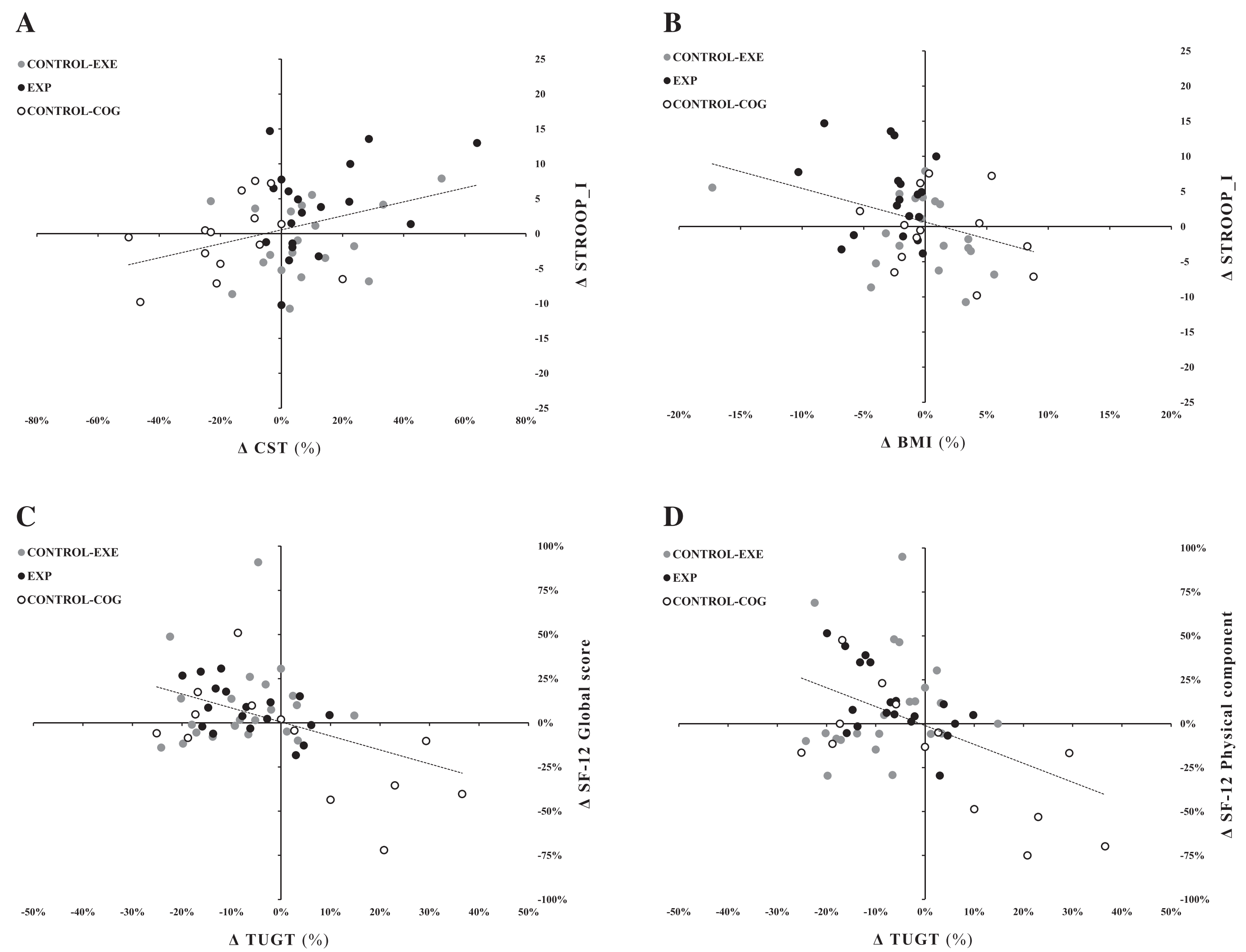

Fig. 2. Relationship between pre to post-intervention changes in Chair-Stand test and Stroop interference score (panel A), BMI and Stroop interference score (panel B), Timed Up and Go test and SF-12 global score (panel C) and Timed Up and Go test and SF-12 physical component (panel D).
Experimental group results are depicted in black full circles, exercise control group in grey full circles and cognitive control group in empty circles.

Regarding physical outcomes, the fact that strength tasks performed in the EFAM-UV® training program were intentionally designed to enable a progressive increase in exercise execution difficulty (and not only in the conventional volume, intensity and density parameters) as participants' skill improve, could explain the broader functional fitness gains achieved by EXP group as compared with CONTROL-EXE (Pesce, 2012). Indeed, this task complexity progression strategy has been particularly recommended when the aim of a training program is to enhance muscle strength synergistically, that is integrated and balanced with other physical fitness components (La Scala Teixeira et al., 2019; Wollesen et al., 2017). Previous studies comparing MCTP and resistance training have showed an improvement in functional fitness following either training, without differences between groups (Forte et al., 2013; Sousa and Mendes, 2013). Neither between-group differences have been previously showed in TUGT and CST following a functional strength training program (i.e., loaded exercises that mimicked activities of daily living) versus a traditional strength training program (Solberg et al., 2013). Therefore, further comparative studies are required to establish whether there is a preferable training mode (i.e., multicomponent, aerobic, resistance, balance) and training methodology (i.e., single vs dual tasking) to boost older adults' functional fitness.

EXP's improvement in HRQOL coincides with previous studies on MCTP, as recently summarized by Bouaziz et al. (2016). Notwithstanding, the authors of the abovementioned review highlight that the impact of MCTP in HRQOL was modest, so our results should be positively rated. This HRQOL enhancement could be mediated by an increase in participants self-efficacy perception (McAuley et al., 2008; Solberg et al., 2013), as EFAM-UV® training program was designed to enable a progressive increase in task difficulty and develop among participants a feeling of mastery. The relationship between pre to post-intervention changes in TUGT and SF-12 physical component and SF-12 global score grounds for this assumption. However, given that pre to post-intervention average changes in TUGT were of 0.39 and 0.58 s in EXP and CONTROL-EXE groups respectively, other mediators rather than self-efficacy perception might explain HRQOL enhancement (i.e., psychological mechanisms such as feelings of emotional wellbeing). Lastly, improvement in body composition (only in the EXP) and blood pressure profile (in the two exercising groups) reinforce the role of exercise as a polypill (Fiuza-Luces et al., 2013; Kasiakogias and Sharma, 2020). Furthermore, all the benefits achieved by exercise groups gain even more relevance when confronted with the negative outcomes showed by the non-exercise group (CONTROL-COG) following the intervention. Decrease in upper-limb strength, lower-limb dynamic balance and physical performance, and worsening of self-perception of global and physical health may indicate that aging, in absence of a regular exercise training, would have deleterious effects on functional fitness and HRQOL in such a short period of time as 30 weeks. Notwithstanding, baseline differences in physical fitness and exercise history could be also responsible for these outcomes.

There are some limitations in our study that should be acknowledged. Randomization of the groups was not possible because we agreed with the senior care centre that participants in the study would be allocated to each one of the three groups according to the facilities' schedule and participants' daily routine. Although no age differences were identified between groups, at baseline EXP showed better functional fitness than the two control groups and better HRQOL than CONTROL-EXE. This greater baseline functional fitness level of EXP could have made it easier for them the performance of neurocognitive exercise tasks. Regarding the external validity of the study, we assume that our results could not be generalized to any neuromotor MCTP. In addition, we acknowledge that our sample might have a physical and cognitive status higher than the normative for a 65+ population. In either case, as pointed out by Solberg et al. (2013), it is also more difficult to improve physical function in older adults with an already initial high baseline physical function. On the other hand, it could be that some individuals with mild cognitive impairment were not identified with MMSE screening; neither could we perform other cognitive assessments apart from Stroop test and we failed to collect participants' educational and socioeconomic data. Lastly, further studies with a control group that performs an executive function-oriented cognitive training (i.e., instead of a memory-focused program) are warranted to verify the potential of neuromotor MCTP as compared with cognitive training programs.

5. Conclusions

EFAM-UV® program could be regarded as a highly suitable training to enhance executive function, functional fitness, HRQOL and body composition in older adults. Moreover, EFAM-UV® program may be deemed as a low time-commitment (twice-weekly instead of more common thrice-weekly exercise training programs) and an easy-to-implement activity in community settings, as it does not require of expensive equipment or specific facilities. Therefore, the main features of a MCTP aimed at synergistically improving executive function and functional fitness should be: being performed in a enriched environment (i.e., to provide decision-making opportunities and require participants to adjust their movements in response to changing stimuli), involve higher coordinative and postural control demands, and enable a progressive increase in exercise execution difficulty (and not only in the conventional volume, intensity and density parameters) as participants' skill improve.

CRediT authorship contribution statement

Conceptualization: IMN CBL.
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Formal analysis: IMN.
Funding acquisition: IMN.
Investigation: IMN AC AR GS CBL.
Methodology: IMN CBL.
Project administration: CBL.
Resources: IMN.
Software: IMN.
Supervision: CBL.
Validation: CBL.
Visualization: IMN.
Writing - original draft: IMN.
Writing - review & editing: IMN AC AR GS CBL.

Declaration of competing interest

None.

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