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The Health of Community-Residing Elderly Study: Effectiveness of Health in Movement, an Adapted Physical Activity Program, in Improving Psychophysical Performance in Community-Residing Older Adults

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Abstract

The aim of this study was to evaluate the association between cognitive function and an Adapted Physical Activity (APA) program in community-residing older adults. The study was carried out in accordance with the principles of the Helsinki Declaration. The final study sample was 60 adults who received either APA plus cognitive training (experimental group, n=34) or APA alone (comparison group, n=26) for 75 minutes per session twice weekly for 12 weeks. A test battery to evaluate executive function and cognitive skills was performed before (baseline) and after the intervention. Significant differences in motor and cognitive performance were observed between the two groups at the final assessment. The experimental group was noted to have improved mobility, physical performance, and pain symptoms, as well as cognitive competencies in the domains typically affected by cognitive decline with advancing age such as memory, orientation, and fine motor skills.

Keywords: Aging; Cognitive decline; Cognitive exercises; Dual task; Physical exercise

Introduction

Recent decades have seen a rapid increase in aging population and in the burden of disability and dependence associated with chronic, debilitating degenerative disease. Maintaining functional independence has become a key priority in the health care of the elderly [1-6]. Although physical inactivity is widespread in the general population, it is especially prevalent among the elderly as a consequence of aging [7-9]. The result is age-related physical decline and decreased quality of life [10]. This situation can be reversed, however, through regular engagement in an Adapted Physical Activity (APA) program. Physical activity is essential for maintaining a healthy lifestyle and to prevent chronic, degenerative illnesses [11,12]. There is ample evidence that physical exercise produces not only physical and psychological benefits in the elderly but also improves cognitive abilities [13]. APA programs can provide a diverse population, including frail older adults, with the opportunity to engage in physical activity appropriate for their ability and individual needs. The core concept of APA is that the physical effort and training required are adjusted to the individual's characteristics and disabilities.

Numerous studies have shown that maintaining physical fitness can delay senescent decline [14,15]. The idea of combining cognitive and motor training rests on the relationship between cognitive and motor function [16-19]. Cognitive rehabilitation is increasingly employed to address cognitive problems in adults and healthy older persons [20-25] or those with traumatic brain injury. The aim is to restore normal functioning and/or to reduce the risk of cognitive loss or decline [26-44].

The present study reports the results of the "Health of Community-Residing Elderly" project that promoted lifestyle changes for improving the health and quality of life of older persons. The exercise program intervention was based on the

principles of APA originally developed in Canada [44], APA is carried out in group sessions that include free-body exercises and body weight exercises with light equipment appropriate for the individual's capacity. Functional evaluation was performed to monitor improvement in physical performance and ability to perform activities of daily living. The study aim was to determine the efficacy of the APA program combined with cognitive training in improving physical performance and cognitive abilities in a group of community-residing older adults.

Material and Methods

Study Design

This single, blind quasi-experimental study was carried out for 12 weeks; assessment was performed at the beginning (baseline) and at the end of the study. The study protocol was approved by the Ethical Committee of the University of Milan. In accordance with the principles of the Helsinki Declaration, informed consent was obtained from all participants.

Participants

The study was part of the "Health of Community-Residing Elderly" project carried out through the "Health in Movement" services. The services are delivered at two facilities, Cesano Boscone and Settimo Milanese, province of Milan, by the Fondazione Sacra Famiglia onlus, a not-for-profit healthcare organization which, for the past 12 years, has provided care to over 2000 persons with disabilities and the elderly at 18 centers throughout the country. The project was created in partnership with the Fondazione Cenci Gallingani onlus, Cesano Boscone, an organization that promotes the delivery of services and development of research in geriatrics. Operated since 2012, the service is attended by over 150 users participating in biweekly group sessions (15 persons per group) at gyms where workouts are performed on large (staircase, parallel bars, wall bar) and small (foams balls, small foam balls, sticks, ankle/wrist weights, elastic bands, minibike) equipment specific for APA. For the study the subjects that started for the first time the activity proposed by the service were enrolled. Inclusion criteria were: age over 60 years, residing in the community, and ability to walk unassisted. Exclusion criteria were: uncontrolled comorbidities, cognitive decline or need for assistance in performing activities of daily living (ADL). The medical examinations were performed by the medical staff of the rehabilitation unit of the Fondazione Sacra Famiglia onlus, while functional evaluations and training programs were carried out to the participants by trained graduates in physical education (kinesiologists). Participants received APA in combination with cognitive training (experimental group, Cesano Boscone facility) or APA alone (comparison group, Settimo Milanese facility). The study protocol for the experimental group consisted of mobility and strength training of the upper and lower limbs, static and dynamic balance exercises, muscle coordination and resistance exercises, with particular focus on respiratory education and thoracic mobility with breathing exercises. The experimental group also received cognitive training for spatiotemporal orientation, short-term and autobiographical memory, semantic verbal games, and fine motor skills. The comparison group received an APA intervention that included general mobility exercises, static and dynamic balance, and strengthening of skeletal muscles. Data from participants who had attended less than 80% of sessions were not included in the analysis. Participation in the study was voluntary. No compensation was offered for participation.

Sessions were conducted twice a week for 12 weeks from March to May 2016. Each session lasted 75 minutes and took place in a dedicated setting. The activities were carried out in two groups of 15 participants each, alternating two workout routines per session. Workout routines comprised exercises for improving balance, muscle strength, mobility, and resistance. The program was standardized so that exercise difficulty could be progressed for both the experimental and the comparison group over the course of the 12 weeks. Training also included respiratory education with breathing exercises such as pursed lip breathing, breathing through a straw, bubble blowing, diaphragmatic breathing, and expiration muscle strengthening. The exercise protocols provide for differences in intensity levels for the experimental group ranging from 45-80% of the maximum heart rate compared to the comparison group ranging from 45-60% of the maximum heart rate. The exercises carried out and outlined in Appendix 1 have been performed following the indications and the attention to safety described in the text of Best-Martini and DiGenova [45].

The experimental group received cognitive training during dual tasks. Cognitive training addressed three major domains of ADL. Different combinations of motor and cognitive activities were performed during each session. The dual tasks comprised strength and balance exercises together with cognitive exercises or combined exercises. During each session a cognitive skill was illustrated and stimulative activities carried out to improve attention, autobiographical memory, informal reality orientation therapy techniques to improve spatiotemporal skills, fine motor movement, and executive function of coordination and control of movement, together with verbal descriptive procedures in progressively increasing difficulty (Appendix 2,3 in the Supplementary Material). All participants underwent assessment at the first (baseline) and the last session.

Measurements

A test battery to assess cognitive and functional abilities was administered at baseline. Assessment comprised clinical evaluation of physical fitness and administration of the Modified Baecke Questionnaire for Older Adults (MBQOA) [46]. The

MBQOA investigates the level of recent physical activity (past 12 months) with regard to sports, leisure, and domestic activities (with 10 items), where the higher the scores the higher the level of physical activity. A score of 3.19 was selected to differentiate sedentary from non-sedentary participants corresponding to more than three hours per week of activity in other physical activities. The Montreal Cognitive Assessment test (MoCA) [47] was administered to evaluate the level of mild cognitive impairment. The test investigates with ten items the cognitive domains of attention and concentration, executive function, memory, language, visuospatial ability, abstraction, calculation, and orientation. The test takes 10 minutes to complete; the maximum score is 30, where a score <26 indicates mild cognitive impairment. For the purposes of the present study, the test domains were analyzed one to one and the clock-drawing test score, which is included in MoCa test, was used to screen for mild dementia. The abdominal circumference was measured for all subjects. This parameter is the minimum circumference between the rib cage and the navel, with the subject standing and with relaxed abdominal muscles. The abdominal circumference was evaluated with a common metric tape, not elastic, positioned at the level of life, according to a horizontal plane parallel to the floor. Life is the narrowest part of the abdomen and is normally just above the upper portion of the lateral border of the iliac crest. If this area is not well evident, the measurement is taken at the navel level. The BMI Body Mass Index was also measured to evaluate the adiposity of the participating subjects. The 6-Minute Walk Test (6MWT) was used to measure functional exercise capacity and independence. This submaximal exercise test entails measurement of total distance (25 meters) walked over a span of 6 minutes at the test-taker's preferred speed with or without pauses or the use of a walking aid. The vital parameters measured during the test were the heart rate and the percentage of oxygen saturation. Max heart rate was determined using the maximum expected for age. For the Timed Up and Go (TUG) test [48], the test-taker sits in a standard height armchair with his/her back against the chair back. On the command "go," the test-taker rises from the chair, walks 3 meters at a comfortable and safe pace, turns, walks back to the chair and sits down. Timing begins at the instruction "go" and stops when the test-taker is seated. For the TUG-Dual Task (TUG-DT), as described above, the test-taker is given verbal instructions to stand up from a chair, walk 3 meters as quickly and safely as possible, cross a line marked on the floor, turn around, walk back, and sit down, while reciting the days of the week backward starting from Sunday. Test-takers are not allowed to stop if they make an error. The number of words, steps, errors, and words per unit of time were recorded. The Dual-Task-Cost (DTC) was calculated for each DT-TUG as follows: [(difference between the TUG Single Task (ST-TUG) and the DT-TUG performance)/TUG performance] ×100. Two examiners conducted the TUG-DT, with one recording the time and number of steps needed to complete the test, and the other recording the number of errors. Participants performed one trial to familiarize themselves with the test procedure.

Cognitive testing was performed in a quiet, empty room; the examiners had received training in administering the tests. Abdominal circumference and elbow mobility in flexion were measured at the beginning and the end of the study to evaluate changes during the course of the study. None of the physical examinations performed before and after the intervention posed any risk for the study participants; all procedures were part of the standard operating procedures of the Health in Movement service. Physical performance was evaluated with the 6MWT and the TUG. Cognitive performance was evaluated with the TUG-DT. Improvement in pain symptoms during ADL was measured using the Visual Analogy Scale (VAS) for pain. The VAS for pain consisted of a horizontal line anchored at one end with the words "no pain" and at the other end with the words "worst pain imaginable (or with equivalent graphic symbols).

At the final assessment physical and cognitive changes over baseline (T0) were measured on the MoCA, joint mobility of the should girdle was measured (maximum elbow flexion angle) using a goniometer, abdominal circumference, and total attendance at the APA sessions.

Statistical Analysis

Descriptive statistics was used to estimate the parameters; t test was applied to compare baseline charactistics. A 2x2 ANOVA model was constructed to examine the effects of the intervention between groups, between subjects (DT training, ST training), time (pre- and post), and within subjects for each dependent variable. The chi-square test was applied to compare percentage. The level of significance was set at P=0.05. SPSS version 24.0 (SPSS-IBM, Armonk, NY, USA) was used for statistical analysis.

Results

Table 1 reports the sociodemographic and clinical characteristics of the study sample; there were no differences between the two groups using t-test at baseline. Table 2 reports the scores for each group before and after the intervention.

	Experimental group		**Comparison group**		**P-value**	**test**
	(n=34)		(n=26)			
Age (yrs)	75.1	(±7.1)	73.7	(±6.4)	0.434	t-test
Sex, female (no, %)	31	(+91)	25	-96	0.42	chi-square
Education level (yrs)	10	(±4.41)	8.8	(±3.36)	0.227	chi-square
Modified Baecke Questionnaire for Older Adults (no. Subjects, %)	10	-27.7	4	-15.4	0.081	t-test
Unless otherwise indicated, all values are the means (±standard deviation)						

Table 1: Baseline characteristics of the study sample.

	Experimental group				Comparision group				**P-value**		
	(n=34)				**(n=26)**				**Between group**		
	T0		**T1**		**T0**		**T1**		**T0**	**T1**	**T0 vs T1**
VAS index (visual analog scale)	3.1	-3.14	1.6	-2.77	0.9	-2.97	0.5	-2.99	0.211	0.002	0.005
Abdominal circumference (cm)	99	-11.89	99.7	-12.76	111	-16.53	114	-15.52	0.396	0.253	0.256
Body-Mass Index (kg/m^2)	27.8	-4.46	27	-4.42	29	-4.71	28.9	-4.78	0.122	0.085	0.085
Shoulder joint mobility (d)	137.1	-13.6	139.7	-12.78	142.5	-15.1	150	-13.25	0.731	0.068	0
6 Minute Walk Test	349.3	-136.5	548.6	-134.85	400	-125.82	562.8	-209.93	0.196	0	0.023
Timed Up and Go Test - Up (no. Rises from chair)	19	-5.66	23.1	-7.14	19.5	-5.83	21.5	-6.76	0.186	0.19	0.01
Timed Up and Go Test - Go (s.)	11.2	-4.26	9.5	-4.45	9.5	-5.24	8.9	-4.01	0.731	0.378	0.405
Dual-task test DTC (s.)	12.8	-6.18	10.1	-5.77	11.8	-6.03	8.8	-4.94	0.558	0.557	0.002
Montreal Cognitive Assessment test (maximum score 30)	18.4	-3.36	23.4	-3.66	19	-2.62	20	-2.66	0.095	0.346	0
Clock- drawing test (maximum score 3)	1.7	-0.86	2.5	-0.7	1.9	-0.85	2.3	-0.74	0.273	0.747	0.031
all values are the means (±standard deviation)											

Table 2: Test results before (T0) and after (T1) intervention.

Comparison between the groups showed significant differences in VAS pain scores, with a more pronounced, statistically significant improvement observed for the experimental group; no statistically significant differences were noted in abdominal circumference and BMI pre-post program. Regarding shoulder mobility there were differences between before and after treatment but no difference between the two groups.

Comparison of pre- and post-intervention values showed statistically significant differences in the 6MWT scores with a higher statistically significance value for experimental group. There was an improvement in number of rises the TUG test; however, the between-group differences were not statistically significant. A reduction in the TUG test go time was not even statistically evident between the two groups or even pre-post treatment.

The DTC was improved with statically significance for both groups, with a greater improvement noted for the experimental group but with no statistically difference.

A statistically significant improvement in was observed between pre and post treatment, similar in both groups.

MoCA test and the clock-drawing test (from MoCA) improved in a statistically significant improvement between T0 and T1 for both groups without statistically significant differences between the experimental and comparison group.

Examining the domains of the Moca test in Table 3 improvements between T0 and T1 were noted for the four domains of visuospatial, attention, abstraction, and spatiotemporal orientation. A highly significant statistical difference was noted for the experimental respect comparison group for visuospatial, attention, and abstraction.

Our data show a significant improvement in effort tolerance and skeletal muscle strength, as measured on the 6MWT, especially for the non-sedentary participants classified according to the MBQOA compared to the control comparison group at baseline (T0). A statistically significant difference between the sedentary participants in the experimental group and the non-sedentary participants in the comparison group was noted at T1. Lower education levels did not correlate with lower scores on cognitive or physical testing. Compliance with the APA program was high with a frequency > 85% for all and no statistically difference between groups; no adverse events related to the study were recorded (Figure 1).

	Experimental group		**Comparison group**						**P-value**		
	(n=34)		(n=26)						Between group		
Montreal Cognitive Assessment test Domains	T0		T1		T0		T1		T0	T1	T0 vs T1
Visuopatial	2.7	(1.34)	4.0	(1.28)	2.7	(1.21)	3.3	(1.10)	0.898	0.038	0.037
Naming	2.5	(0.707)	2.8	(0.478)	2.8	(0.43)	2.9	(0.33)	0.109	0.244	0.244
Attention	4.4	(1.04)	5.3	(0.93)	4.9	(1.03)	4.9	(0.90)	0.08	0.005	0.005
Language	1.5	(0.748)	2.0	(0.90)	1.6	(1.07)	2.1	(0.86)	0.478	0.894	0.834
Abstraction	1.1	(0.81)	1.64	(0.54)	1.3	(0.71)	1.5	(0.71)	0.063	0.008	0.007
Memory	0.8	(0.94)	1.5	(0.93)	0.9	(1.11)	1.4	(1.41)	0.64	0.52	0.518
Orientation	5.8	(0.44)	23.1	(7.14)	5.8	(0.37)	21.5	(6.76)	0.051	0.905	0.009
all values are the means (±standard deviation)											

Table 3: MoCa test scores before (T0) and after (T1) intervention.

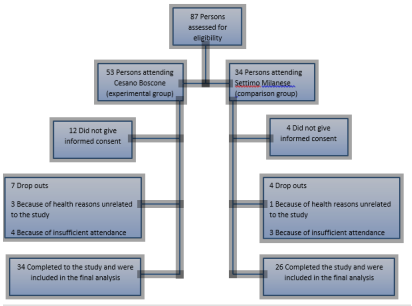

Figure 1: Study flow diagram.

Discussion

Our data show that an APA program combined with cognitive training (dual task condition) can help to maintain physical function and cognitive competences, with the benefit of preserving independence and quality of life in older adults. Our study indicates that training through cognitive stimulation coupled with APA interventions and respiratory education can be combined to improve cognitive domains (e.g., executive function, visuospatial abilities), delay the onset of dementia, and potentially aid in early identification of the illness. This is particularly so when, as in the present study, an APA program is combined with dual tasking.

The program intervention was found to be effective in improving mobility, physical and cognitive performance, and reducing pain symptoms without causing significant side effects. Furthermore, respiratory education was useful for improving physical performance, as reported elsewhere [49].

Comparison of the two groups showed that both programs led to improvement in physical performance (greater effort tolerance, skeletal and respiratory muscle strength) with particular benefit for improving and/or maintaining cognitive abilities (e.g., short- and long-term memory, verbal fluency, attention, and fine motor skills), as seen for the experimental group on the clock-drawing test.

A novel finding of our study was the improvement in cognitive capacities after exercise program intervention in both groups. The greater improvement seen for the experimental group underscores the benefit of an APA program that includes respiratory education and physical exercises in combination with cognitive training to improve verbal fluency, attention capacity, and fine motor skills, which are often associated with cognitive impairment in performing ADL. The small sample size notwithstanding, the study provides encouraging results: combined training at vigorous exercise intensity (80% heart rate) to improve physical and maintain or improve cognitive abilities can be an effective strategy to prevent or delay cognitive decline in the elderly. An environmental setting enriched with group activities and varied exercise routines is likely to stimulate cognitive plasticity and provide an additional protective factor within a wider prevention intervention than physical exercise alone as described also by Ben-Sadoun and Røe [50,51].

It is necessary to clarify that a potential limitation of this study is determined by the fact that, as described in the materials and methods, there were differences in the intensity of the exercise performed in the two study groups, together with the number of repetitions and even the exercises used they could help explain differences rather than additional cognitive training.

Our study results underline the importance of maintaining an active lifestyle into older age through regular group physical and structured cognitive stimulation activities, social participation, and pursuit of hobbies and interests. Engagement in such activities could have neuroprotective effects and help to delay the onset of cognitive decline associated with aging [52]. APA program interventions should be an integral part of health care for the elderly.

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Author Contributions Statement

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All authors were involved in to conception and design of the study.

GG and AL have performed all medical visits of subjects under study.

IG and SD performed training session and the functional evaluations of subjects.

FP performed the statistical analysis.

IG and FP analyzed and interpreted the data regarding the study and were some major contributors in writing the manuscript.

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Ethics Approval and Consent to Participate

The study protocol was approved by the Ethical Committee of the University of Milan on April 18 2016.

Consent for Publication

Informed consent was obtained from all participants including consent for publication of their data.

References

1. Schäfer S, Huxhold O, Lindenberger U 1(2006) Healthy mind in healthy body? A review of sensorimotor cognitive interdependencies in old age. Eur Rev Aging Phys Act 3: 45-54.
2. Daniel Schoene, Trinidad Valenzuela, Stephen R Lord, Eling D de Bruin Schoene, et al. (2014) The effect of interactive cognitive-motor training in reducing fall risk in older people: a systematic review. BMC Geriatrics 14: 107.
3. In Larson EB, Wang L, Bowen JD, McCormick WC, Teri L, et al. (2006) Exercise is associated with reduced risk for incident dementia among persons 65 years of age and older. Ann Intern Med 144: 73-81.
4. Bieryla KA, Dold NM (2013) Feasibility of Wii Fit training to improve clinical measures of balance in older adults. Clin Interv Aging 8: 775-781.
5. Chao YY, Scherer YK, Wu YW, Lucke KT, Montgomery CA (2013) The feasibility of an intervention combining self-efficacy theory and Wii Fit exergames in assisted living residents: a pilot study. Geriatric Nurs 34: 377-382.
6. Berchicci M, Lucci G, Di Russo F (2013) Benefits of physical exercise on the aging brain: the role of the prefrontal cortex. J Gerontol A: Biol Med Sci 68: 1337-1341.
7. Schoene D, Valenzuela T, Lord SR, de Bruin ED (2014) The effect of interactive cognitive motor training in reducing fall risk in older people: a systematic review. BMC Geriatr 14:107.
8. Kovács E, Prókai L, Mészáros L, Gondos T (2013) Adapted physical activity is beneficial on balance, functional mobility, quality of life and fall risk in community-dwelling older women: a randomized single-blinded controlled trial. Eur J Phys Rehabil Med 49: 301-310.
9. Hamer M, Chida Y (2009) Physical activity and risk of neurodegenerative disease: a systematic review of prospective evidence. Psychol Med 39: 3-11.
10. Panzarino M, Gravina A, Carosi V, Crobeddu P, Tiroli A, et al. (2017) Cardiovascular and hemodynamic responses to adapted physical exercises in very old adults. Aging Clin Exp Res 29: 419-426.
11. Heyn PC, Johnson KE, Kramer AF (2008) Endurance and strength training outcomes on cognitively impaired and cognitively intact older adults: a meta-analysis. J Nutr Health Aging 12: 401-409.
12. Barber SE, Clegg AP, Young JB (2012) Is there a role for physical activity in preventing cognitive decline in people with mild cognitive impairment? Age and ageing 41: 5-8.
13. Angevaren M1, Aufdemkampe G, Verhaar HJ, Aleman A, Vanhees L (2008) Physical activity and enhanced fitness to improve cognitive function in older people without known cognitive impairment. Cochrane Database Syst Rev 16: CD005381.
14. Andreas Lauenroth, Anestis E Ioannidis, Birgit Teichmann, Laurenroth (2016) Influence of combined physical and cognitive training on cognition: a systematic review. BNC Geriatric 16: 141.
15. Priest AW, Salamon KB, Hollman JH (2008) Age-related differences in dual task walking: a cross sectional study. J Neuroeng Rehabil 5: 29.
16. Tait JL, Duckham RL, Milte CM, Main LC, Daly RM (2017) Influence of Sequential vs. Simultaneous Dual-Task Exercise Training on Cognitive Function in Older Adults. Front Aging Neurosci 9: 368.
17. Wadley VG, Okonkwo O, Crowe M, Ross-Meadows LA (2008) Mild cognitive impairment and everyday function: evidence of reduced speed in performing instrumental activities of daily living. Am J Geriatr Psychiatry 16: 416-424.
18. Jak AJ (2012) The impact of physical and mental activity on cognitive aging. Curr Top Behav Neurosci 10: 273-291.
19. Colcombe S, Kramer AF (2003) Fitness effects on the cognitive function of older adults a meta-analytic study. Psychol Sci 14: 125-130.
20. Oswald W, Gunzelmann T, Rupprecht R, Hagen B (2006) Differential effects of single versus combined cognitive and physical training with older adults: the SimA study in a 5-year perspective. Eur J Ageing 3: 179-192.
21. Theill N, Schumacher V, Adelsberger R, Martin M, Jancke L (2013) Effects of simultaneously performed cognitive and physical training in older adults. BMC Neurosci 14: 103.
22. Colcombe SJ, Kramer AF, Erickson KI, Scalf P, McAuley E, et al. (2004) Cardiovascular fitness, cortical plasticity, and aging. Proc Natl Acad Sci U S A 101: 3316-3321.
23. Schaefer S, Schumacher V (2010) The interplay between cognitive and motor functioning in healthy older adults: findings from dual-task studies and suggestions for intervention. Gerontology 57: 239-246.
24. Pichierri G, Wolf P, Murer K, De Bruin ED (2011) Cognitive and cognitive-motor interventions affecting physical functioning: a systematic review. BMC Geriatr 11: 29.
25. Ball K, Berch DB, Helmers KF, Jobe JB, Leveck MD, et al. (2002) Effects of cognitive training interventions with older adults: a randomized controlled trial. JAMA 288: 2271-2281.
26. Bherer L, Kramer AF, Peterson MS, Colcombe S, Erickson K, et al. (2008) Transfer effects in task-set cost and dual-task cost after dual-task training in older and younger adults: further evidence for cognitive plasticity in attentional control in late adulthood. Exp Aging Res 34: 188-219.
27. Hsu CL, Nagamatsu LS, Davis JC, Liu-Ambrose T (2012) Examining the relationship between specific cognitive processes and falls risk in older adults: a systematic review. Osteoporos Int 23: 2409-2424.
28. Silsupadol P, Shumway-Cook A, Lugade V, van Donkelaar P, Chou L-S, Mayr U, et al. (2009) Effects of single-task versus dual-task training on balance performance in older adults: a double-blind, randomized controlled trial. Arch Phys Med Rehabil 90: 381-387.
29. James BD, Wilson RS, Bennett DA (2011) Late-life social activity and cognitive decline in old age. J Int Neuropsychol Soc 17: 998-1005.
30. Borella E, Carretti B, Riboldi F, De Beni R (2010) Working memory training in older adults: evidence of transfer and maintenance effects. Psychol Aging 25: 767.
31. Brehmer Y, Westerberg H, Bäckman L (2012) Working-memory training in younger and older adults: training gains, transfer, and maintenance. Front Hum Neurosci 6: 63.

32. Buschkuehl M, Jaeggi SM, Hutchison S, Perrig-Chiello P, Däpp C, et al. (2008) Impact of working memory training on memory performance in old-old adults. Psychol Aging 23: 743-753.

33. Cavallini E, Pagnin A, Vecchi T (2003) Aging and everyday memory: the beneficial effect of memory training. Arch Gerontol Geriatr 37: 241-257.

34. Edwards J, Wadley V, Myers R, Roenker DL, Cissell G, et al. (2002) Transfer of a speed of processing intervention to near and far cognitive functions. Gerontology 48: 329-340.

35. Richmond LL, Morrison AB, Chein JM, Olson IR (2011) Working memory training and transfer in older adults. Psychol Aging 26: 813-822.

36. Verghese J, Mahoney J, Ambrose AF, Wang C, Holtzer R (2010) Effect of cognitive remediation on gait in sedentary seniors. J Gerontol Ser A Biol Med Sci 65: 1338-1343

37. Willis SL, Tennstedt SL, Marsiske M, Ball K, Elias J, et al. (2006) Long-term effects of cognitive training on everyday functional outcomes in older adults. JAMA 296: 2805-2814.

38. O'Dwyer ST, Burton NW, Pachana NA, Brown WJ (2007) Protocol for fit bodies, fine minds: a randomized controlled trial on the affect of exercise and cognitive training on cognitive functioning in older adults. BMC Geriatr 7: 23.

39. Law LL, Barnett F, Yau MK, Gray MA (2014) Effects of combined cognitive and exercise interventions on cognition in older adults with and without cognitive impairment: a systematic review. Ageing Res Rev 15: 61-75.

40. Wollesen B, Voelcker-Rehage C (2014) Training effects on motor–cognitive dual-task performance in older adults. Eur Rev Aging Phys Act 11: 5-24.

41. Caspersen CJ, Powell KE, Christenson GM (1985) Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep 100: 126-131.

42. Bahar-Fuchs A, Clare L, Woods B (2013) Cognitive training and cognitive rehabilitation for mild to moderate Alzheimer's disease and vascular dementia. Cochrane Database Syst Rev 6: CD003260.

43. Cress ME, Buchner DM, Prohaska T, Rimmer J, Brown M, et al. (2005) Best practices for physical activity programs and behavior counseling in older adult populations. J Aging Phys Act 13: 61-74.

44. Hutzler Y, Sherrill C (2007) Defining adapted physical activity: International perspectives. Adapted Physical Activity Quarterly 24: 1-20.

45. Best Martini E, DiGenova KAJ (2014) Exercise for Frail Elders. 2ed HumanKinetics USA.

46. Voorrips IE, Ravelli AC, Dongelmans PC, Deurenberg P, Van Steveren WA (1991) A physical activity questionairre for the elderly. Med. Sci. Sports Exerc 23: 974-979.

47. Nasreddine ZS, Phillips NA, Bédirian V (2005) The Montreal cognitive assessment, MoCA: a brief screening tool for mild cognitive impairment. J Am Geriatr Soc 53: 695-699.

48. Podsiadlo D, Richardson S (1991) The time "Up and Go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 39: 142-148.

49. Lotters F, Tol B, Kwakkel G (2002) Effects of controlled inspiratory muscle training in patients with COPD: a meta analysis. Eur Respir J 20: 570-576.

50. Ben-Sadoun G, Sacco G, Manera V, Bourgeois J, König A, et al. (2016) Physical and Cognitive Stimulation Using an Exergame in Subjects with Normal Aging, Mild and Moderate Cognitive Impairment. Alzheimers Dis 53: 1299-1314.

51. Røe C, Preede L, Dalen H, Bautz-Holter E, Nyquist A, et al. (2016) Does adapted physical activity-based rehabilitation improve mental and physical functioning? A randomized trial. Eur J Phys Rehabil Med 54: 419-427.

52. Bugg JM1, Shah K, Villareal DT (2012) Head D Cognitive and neural correlates of aerobic fitness in obese older adults. Exp Aging Res 38: 131-145.