Life Span and Disability XXIII, 1 (2020), 65-83

The role of physical activity and brain training on cognitive functions and well-being in older adults

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Abstract

In the last few decades, the relationship between physical conditions and mental health in the elderly has increasingly attracted the interest of researchers and professionals. Evidence shows that physical activity is a protective factor as it determines enormous benefits on both cognitive functioning and well-being. Based on these premises, the present research aims to evaluate the relationship between Physical Activity, Cognitive Function, namely attention and memory, and social well-being in a volunteer sample of sixty-one Italian old adults, aged between sixty-five and eighty-three years. Participants were administered the Short Form Health Survey, the Trail Making Test and the Serial Repetition Bi-syllabic Words Test, before and after a training program designed by a team of different specialists within a joint project. Findings showed that physical activity has positive effects on both cognitive functions and quality of life, thus emphasizing the additional role of training programs

Received: November 16, 2019; *Revised:* April 28, 2020; *Accepted*: May 18, 2020

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Funding: This research is part of an intervention project funded by the Sicily Region Health Department. Service 5 DASOE. Action 2.3.1 PSN 2012: Agreement between ASP of Enna and CONI Sicilia on the Promotion of physical activity adapted for elderly people over 64 at low risk.

(including cognitive training exercises) as cost-effective opportunities for elderly people to socialize (Pace & Zappulla, 2013).

Keywords: Aging; Cognitive functions; Well-being; Adapted physical activity; Training programs.

1. Introduction

There has been a meaningful growing interest in recent years about the effects of physical activity (PA) on the aging process (Taylor, Cable, Faulkner, Hillsdon, Narici, & Van Der Bij, 2004). In Europe, life expectancy has steadily risen by three months/year for the last 160 years. According to the Italian National Institute of Statistics - ISTAT (2017), Italy currently represents the oldest country in the world according to the aging index (measured as the ratio between the percentages of citizens aged over sixty-five and under fifteen years). Italians aged > sixty-five years account for 22.3% of the population, and the overall average age is 44.9 years. The epidemiological transition described above has highlighted the importance of promoting physical health and psychosocial well-being among elderly citizens (Prochaska & Prochaska, 2016).

In this context, the role played by PA is considerable (Kanning & Schlicht, 2008; Musich, Wang, Hawkins, & Greame, 2016; Rezaei, Montazar, Valiollah Mousavi, Poor's, & Hosseini, 2018; Utvić, Pejčic, Arsenijević, & Lilić, 2018; Gyasi, 2019). Several studies have reported that people engaged in regular PA show higher levels of cognitive function (CF) and decreased risk of cognitive decline (Lautenschlager, Flicker, Foster, van Bockxmeer, Xiao, Greenop *et al.*, 2008; Brown, Peiffer, Sohrabi, Gupta, Rainey-Smith, Taddei *et al.*, 2012; Smith, Nielson, Woodard, Seidenberg, & Rao, 2013; Büla, 2016).

According to research studies, cognitive abilities decrease across multiple domains with advancing age (Craik & Salthouse, 2000), with particularly evident decline after the age of sixty. According to McAuley and colleagues (2006), one possible protective mechanism for maintaining cognitive health is PA. Much evidence has demonstrated that physical exercise affects brain plasticity, which influences cognition. In fact, experimental and clinical studies have reported that PA induces structural and functional changes in the brain, producing enormous biological and psychological benefits. Neuroimaging studies further support these observations in showing larger hippocampal volume among older individuals with higher fitness habits (Colcombe, Erickson, Scalf, Kim, Prakash, McAuley *et al.*, 2009; Smith *et al.*, 2013; Pace, D'Urso, & Zappulla, 2018).

The results of cross-sectional and epidemiological studies showed that PA enhances cognitive functions in older adults (Lista & Sorrentino, 2010; Fernandes, Arida, & Gomez-Pinilla, 2017; Loprinzi, Frith, Edwards, Sing, & Ashpole, 2018), by improving memory abilities, efficiency of attentional

processes, and executive-control processes (Kramer, Hahn, Cohen, Banich, McAuley, & Harrison, 1999; Colcombe & Kramer, 2003; Grego, Vallier, Collardeaul, Rousseu, Cremieux, & Brisswalter, 2005; Winter, Breitenstein, Mooren, Voelker, Fobker, & Lechtermann, 2007; Chieffi, Messina, Villano, Messina, Valenzano, Moscatelli *et al.*, 2017).

This fact was confirmed by Rezaei and colleagues (2018) that showed in their study a positive and significant correlation between PA and cognitive function in terms of short-term memory, visuo-spatial skills, executive functions, attention, concentration, working memory, language, and orientation to time and space. Moreover, Erickson, Hillman and Kramer (2015), showed that moderate PA is associated with increased CF, especially in executive functions. In particular, their longitudinal study indicated that self-reported PA was associated with a 40% reduction in the risk of cognitive problems.

Furthermore, the results of a systematic review on the relationship between PA and CF in older Chinese adults indicated exercised-induced improvements in multiple domains of cognitive functions (i.e., global cognitive function, memory, executive function, attention, language, and processing recourses). The review demonstrates that older Chinese adults, especially those with long-term engagement, are likely to have a lower risk of cognitive impairment, a better cognitive health and increased cognitive performance later in life (Lü, Fu, & Liu, 2016).

In a study on the effects of exercise training on cognitive functions, Netz and colleagues (2005) found how older adults in the moderate-fitness group compared to the low-fitness group achieved significantly better results on the global cognitive score. The trend for superior cognitive scores in the moderate-fitness group compared to scores in the low-fitness group was unequivocal in regards to attention and executive function, both in terms of accuracy and reaction times.

Predovan, Fraser, Renaud and Bherer (2012) employed sedentary older adults (i.e., a lack of or irregular physical activity) in their study to determine whether the benefits of aerobic exercise were extended to different executive processes measured by using a modified version of the Stroop task. They showed that subjects who participated in the three-month aerobic training improved their inhibition/switching Stroop test performance compared to the control group.

Moreover, the study carried out by Brown and colleagues (2012) showed that intensity rather than quantity of PA may be more important in the association between PA and CF. In fact, improved performance in numerous

cognitive domains, including speed of processing, memory, and mental flexibility has been observed in participants who reported greater intensity of physical activity (Chodzko-Zajko, Wojtek, Moore, & Kathleen, 1994; Boutcher, 2000; van Gelder Tijhuis, Kalmijn, Giampaoli, Nissinen, & Kromhout, 2004; Angevaren, Vanhees, Wendel-Vos, Verhaar, Aufdemkampe, Aleman *et al.*, 2007; Bixby, Spalding, Haufler, Deeny, Mahlow, Zimmerman *et al.*, 2007).

Milczarek, Zegarski and Sikorski (2009) examined the influence of adapted physical training on CF in elderly people. To evaluate cognitive performance, two tests were used: a face/name association test and a trial making test. The tests were administered before and immediately after a training program: after the elderly group had participated in a three-month physical training with the face/name association test, a significant improvement was observed in average results, as well as in the trial making test (the combination of digits and the combination of digits and letters). This finding showed that systematic PA can limit or partly stop the decrease of cognitive functions that are related to age.

Moreover PA, besides providing health benefits (e.g. cognitive functioning), promotes psychosocial well-being (SWB) in terms both of physical and mental health of citizens in the later stage of life (Lampinen, Heikkinen, Kauppinen, & Heikkinen, 2006; Moran, Van Cauwenberg, Hercky-Linnewiel, Cerin, Deforche, & Plaut, 2014; Awick, Wojcicki, Olson, Fanning, Chung, & Zuniga, 2015).

A study by Lee and Russell (2003) analyzed the relationship between PA and SWB cross-sectionally and longitudinally. SWB was measured with the four mental health subscales of the Medical Outcomes Study Short Form (SF-36). The sample of the cross-sectional study included 10,063 women aged between seventy and seventy-five. The results showed that higher levels of PA were associated with increased SWB. Lee and Russell performed a follow up with these women three years later. Compared to women who remained inactive, women who started some PA (exercise adoption) or women who maintained PA (maintenance group) showed an increase in SWB, whereas women who did not remain physically active (cessation group) showed a significantly greater decrease in SWB.

An interesting review by Taylor and colleagues (2004) considered the evidence for a causal relationship between programmed physical activity and psychosocial health: American women up to sixty-five years of age who wanted to be fit thought that a fit person could manage health problems more efficiently (Lucas, Orshan, & Cook, 2000). Again, Crombie and

colleagues (2004), found that 95% of their participants (409 of older Scottish people aged sixty-five to eighty-four years) believed that exercise was related to health.

Furthermore, an Italian study by Delle Fave and colleagues (2018) found that adapted physical activity (APA) programs were positively associated with psychosocial health and increased quality of life in older age. The authors examined emotional, psychological, and social components of well-being, together with satisfaction in life (Leanza, Zanghì, Leanza, Leanza, Passanisi & Giaimo, 2015; Pellerone, Cascio, Costanzo, Gori, Pace, & Craparo, 2017). A sample of fifty-eight Italian adults aged from sixty-seven to eighty-five years were involved in two APA training programs based on a physical and functional assessment: thirty-nine of them joined a program of adapted motor activity, while the remaining nineteen participants attended a variant program specifically designed for people with osteoporosis. The findings highlighted that, besides physical benefits, participants reported significantly more adaptive emotion regulation strategies together with higher levels of well-being after both training programs.

Finally, a study by Drouin, Delisle, Larouche, Normand and Simard (1994) showed that 1,060 active elderly adults aged from sixty to eighty-five years who participated in an APA program for three months obtained higher perception scores for physical, psychological, and social health compared to sedentary elderly adults.

2. Aims and hypothesis

Based on the aforementioned assumptions supported by the literature, the present study aimed at exploring the relationship between PA, CF, namely attention and memory, and SWB among the elderly population.

A team of different specialists (i.e. psychologists, medical doctors, and kinesiologists) was built in the framework of the project "*Optimization and dissemination APA (adapted physical activity) 2018/2020 - physical efficiency of aging individuals*" to design a training plan and to test its efficacy through a longitudinal research model. These specialists came from different institutions: C.O.N.I. (Italian National Olympic Committee - Regional Committee of Enna, Italy), Department of Health Education and Promotion of the "Umberto I" Hospital (Enna, Italy), and Faculty of Human and Social Sciences of the Kore University (Enna, Italy).

3. Methods

3.1. *Participants*

The study involved sixty-one volunteer Italian old adults (nineteen males, 31.1%, and 42 females, 68.9%), aged from sixty-five to eighty-three years (M = 72.84 years, SD = 5.05) from Enna and province (i.e., Villarosa and Calascibetta), a relatively small urban area in the middle of Sicily (Italy). As regards the level of education of participants 29.5% had attended upper secondary school, 39.4% primary school, 29.5% lower secondary school, and 1.6% university. 62% were housewives, 24% were employees, and 4% were freelancers, while the majority of the sample consisted of retirees (84.5%). Regarding demographic characteristics, most of the participants (63.3%) lived with their partner, 8.4% of participants lived alone, 3.6% were divorced, and 25% were widowers. 82.1% of participants, primarily sedentary ones, reported having one or more leisure time activity (e.g. reading, voluntary activities, attending cultural events). 45.9% of participants occasionally played sports (e.g., gym-exercises).

3.2. *Instruments*

The *Short Form Health Survey* (SF-36; Apolone & Mosconi, 1998) assesses the mental and physical health status and eight generic health concepts including psychical functioning (PF), role limitations due to physical health (RP), bodily pain (BP), general health (GH), vitality (VI), social functioning (SF), role limitations due to emotional health (RE), and mental health (MH). Moreover, two synthetic indices of physical health (Physical Component Summary, PCS) and mental health (Mental Component Summary, MCS) can be calculated [(example items, *general health scale*: In general, you would say that your health is: from excellent (1) to poor (5); *physical problems limitations scale*: In the past 4 weeks, have you experienced the following problems at work or in other daily activities due to your physical health? Answer yes or no to each question: I reduced time spent on work or other activities; I had to limit certain types of work or other activities, etc.; *limitations physical and emotional problems scale*: during the past 4 weeks, to what extent have your physical health or emotional state interfered with normal social activities with family, friends, neighbors, groups to which you belong?: I made less than I wanted, etc.; *mental health scale*: the following questions refer to how you have felt in the

past 4 weeks. Answer each question by choosing the answer that most closely matches your case. How long in the past 4 weeks have you felt: lively bright (the participant could answer from 1 always to 6 never)]. The scale has thirty-six items that are scored and summed according to a standardized protocol and expressed as a score on a 0-100 scale for each of the eight health concepts. The scale reliability' scores (Cronbach's alpha) range from .77 to .82.

The *Trail Making Test* (TMT-A/TMT-B; Reitan, 1958) is used in neuropsychological clinical practice to assess specific aspects of attention and executive functions. The test is composed by two parts (A and B), as well as it requires drawing a trail between elements. TMT-A requires an individual to draw lines sequentially connecting twenty-five encircled numbers distributed on a paper sheet. Task demands are similar for TMT-B with the exception that participants have to alternate between numbers and letters (e.g., 1, A, 2, B, 3, C, etc.). According to the literature (Lezak, 1995; Mitrushina, Boone, Razani, & D'Elia, 2005; Strauss, Sherman, & Spreen, 2006), TMT-B, besides attention, involves additional "executive function" demands (e.g. cognitive alternation/flexibility, inhibition/interference control, working memory, mental tracking, and attentional set-shifting). The score on each part is the amount of the time required to complete each task. In particular, total time for parts A and B were recorded in seconds, representing the TMT-A and TMT-B direct scores respectively. Three derived scores were also calculated: a difference score (B - A), a ratio score (B:A), and a log score (B:A). This instrument is widely used in clinical and neuropsychological contexts and protocols (and not) because it showed good psychometric properties and a standardized procedure (e.g., Zhao, Guo, Li, Zhou, Wang, & Hong, 2013).

The *Serial Repetition Bi-syllabic Words Test* (SRBWT; Spinnler & Tognoni, 1987) evaluates short-term auditory-verbal memory, through a standardized procedur*e (Ibidem)*. The researcher reads the word sequences aloud at the rate of one word every two seconds, and at the end of each sequence the examiner asks the participant to repeat the words heard. Three strings are presented for each length. The researcher reads the word sequences at the rate of a word every two seconds. If the participant repeats two out of three strings correctly, he/she passes to the longest string: e.g.: fur, rooster, cash (first string); bread, nose, sky (second string); bone, light, wood (third string). If the participants recall correctly at least two out of three strings, it is possible to move on to the longer string. The participant's

span is represented by the longest series for which at least two strings have been correctly recalled.

3.3. *Procedure*

After presenting the research and obtaining written informed consent from participants, a medical-doctor assessed their current physical functioning at the Umberto I Hospital of Enna for eligibility. After the assessment, ten out of seventy-one volunteers (3.70%) did not meet the study criteria, as they did not complete the measures used in the present study.

Before the start of the training program (T1), participants provided personal information about their socio-demographic characteristics and leisure time activities. They also filled out questionnaires measuring the variables of interest in the current study (i.e. attention, memory, and quality of life).

Afterwards, participants joined a program consisting of structured APA group sessions that took place in a gym.

A team designed the activities with the aim of preventing physical and functional decay and promoting health and wellness in elderly adults through physical activity.

Participants were randomly divided into two groups of twenty individuals each, and attended weekly sixty-minute sessions for six months. The sessions were run by physical educational teachers adequately prepared by a kinesiologist to carry out the same program for the elderly consisting of free-body exercises. Indeed, the program included intense physical activities testing aerobic endurance, strength, balance, coordination, and flexibility.

Moreover, participants took part in a specific training to improve cognitive functioning (attention and memory) and to increase emotional and social skills. These latter activities were designed by a team of specialized psychologists and were carried out once a month for three months.

In the first meeting, participants played “the memory card game” in order to enhance both attention and memory functions and were randomly divided in two groups.

Participants had eighty cards that included pairs of two. After mixing them up, they turned cards over and had to choose two cards to be turned over, then cards were turned upside down again. The objective was to remember where the cards were and find matches. The group with the most matches at the end of the game won.

In the second meeting, participants were divided into two groups, and each group had to build a story (beginning, middle, and end). The images were specifically chosen from the Thematic Apperception Test (T.A.T.; Murray, 1943). The objective of this activity was to develop the socio-relational skills of participants through group activities. In the third meeting, participants played a psychological game called "The secret refuge" (Manes, 2016) that was designed to let participants remember and reflect about modalities employed during childhood to find comfort in difficult situations. This activity allowed participants to recall and share traumatic events in order to gain a greater self-awareness. At the end of the program (T2), participants were invited again to fill in the same series of psychological questionnaires administered at T1.

4. Data analysis and results

The paired sample *t*-test was carried out to verify any levels of improvement of the study variables among participants at time 1 and time 2 (see Tab. 1). All statistical analyses were carried out using the Statistical Package for Social Science (SPSS), version 24 for Windows. The analyses were carried out on the whole group of participants, because similar results were obtained for males and females.

Table 1 - *Means (M) and Standard Deviations (DS) of study variables in T1 and T2*

Variables	T1	T2	$t_{(60)}$
	M (DS)	*M (DS)*	
PF	26.60 (5.20)	27.65 (5.30)	-1.43
RP	6.31 (1.60)	5.60 (1.70)	2.31**
BP	7.70 (1.90)	6.80 (2.03)	-2.66**
GH	16.15 (3.33)	16.30 (4.30)	.71
VI	16.70 (3.30)	16.95 (3.60)	-.05
SF	8.40 (1.46)	8.51 (1.58)	1.01
RE	4.81 (1.14)	4.62 (1.30)	.95
MH	20.72 (5.80)	21.70 (5.40)	-1.30
PCS	41.31 (6.60)	41.40 (7.20)	-.081
MCS	33.05 (8.10)	34.50 (7.03)	-.88
TMT-A	197.98 (542.90)	157.38 (345.20)	.48
TMT-B	624.3 (202.80)	244.63 (154.40)	1.43
SRBWT	1.98 (1.20)	3.01 (.90)	-6.90**

* $p < .05$; ** $p < .01$

Significant differences emerged in RP ($t_{(60)}$ = 2.31, p < .01): participants reported higher levels in T1 (M = 6.31; SD = 1.60) than in T2 (M = 5.60, SD = 1.70). Significant differences emerged also in BP ($t_{(60)}$ = -2.66, p < .01). In particular, in T1, participants obtained higher scores (M = 7.70; SD = 1.89) compared to T2 (M = 6.81, SD = 2.02).

Finally, significant differences were found in the SRBWT ($t_{(60)}$ = -6.90, p < .001). Specifically, participants reported lower levels in T1 (M = 1.98; SD = 1.21), than in T2 (M = 3.01, SD = .90).

5. Discussion

Considering the shortage of literature that includes specific interventions for elderly, the study aims at verifying the potential benefits that APA and socio-emotional and cognitive training can have on psychophysical health and on some main cognitive functions (memory and attention) among elderly people. The literature has emphasized that in old age there is a deterioration of mnestic skills (Khezri, Arab Ameri, Hemayattalab, & Ebrahimi, 2014) and attentional functions (Brayne, Gill, Paykel, Huppert, & O'Connor, 1995). Therefore, it is essential to identify interventions that are aimed at stimulating these skills to, if not improved, try to maintain them. In this sense, the literature underscores how specific interventions concerning physical and relational skills could improve the psychophysical health of the person (Lok, Lok, & Canbaz, 2017).

Moreover, physical activity has also positive effects on cognitive functions, as it increases cell proliferation and longevity together with the production of neurotransmitters in different neurological regions that are involved in cognitive functions (Erickson *et al.*, 2015; Rezaei *et al.*, 2018). Indeed, our study suggests that training based on shared physical activity, memory, and attention stimulation greatly improves the perception of body pain and limitations due to physical health. In other words, the constant cognitive and physical training and the care of psycho-relational well-being greatly improve one’s perception of pain, as well as his/her whole well-being. It’s likely that training has influenced the participants’ self-efficacy beliefs (Bandura, 1982, 1997). In this sense, the person, thanks to the positive stimulations obtained from training and social exchanges, felt stronger and learned how to better manage his/her pain, experiencing positive perceptions about his/her health because he/she knows how to act and perform to feel comfortable.

Furthermore, the training improved the short-term auditory-verbal memory for participants in our group. Thus, cognitive and psychophysical stimulation proved to be a significant predisposing factor in the improvement of short-term auditory-verbal memory in older age.

These findings suggest how acting on several fronts at the same time (cognitive, physical and relational) can increase cognitive functions and general well-being conditions. In other words, this study suggests to look at the person as the result of a complex social and cognitive architecture that works only if stimulated in a sufficient manner (Guzzo, Lo Cascio, & Pace, 2013).

Consequently, it is sensible to stimulate not only cognitive or physical functions, but to also consider the interplay between them, as well as the centrality of socio-relational aspects, because they may be significant protective factors in elderly adults. Despite the aforementioned strengths, the present study suffered from some limitations.

First of all, we enrolled a sample made up of volunteers. Compared to a random sample, our participants may have been strongly biased by highly positive expectations of the training outcomes.

As for memory evaluations, we only assessed short-term auditory-verbal memory. Future research will benefit from the use of other instruments in order to create a better picture of the role of cognitive and physical stimulations on memory performance and well-being in elderly adults (Pace, D'Urso, Passanisi, Cacioppo, Mangialavori, & Zappulla, 2019). Despite this, the present data seem to confirm the perspective that the interplay between different factors (physical, cognitive, and relational) may play a crucial role on elderly people's cognitive abilities and quality of life.

This program contributes to extending those ones still present (van Uffelen, Chin A Paw, Hopman-Rock, & van Mechelen, 2008; Bherer, Erickson, & Liu-Ambrose, 2013) because it leverages an integration of activities (i.e., psychological and physical) for the elderly. Furthermore, it underlined how the consolidation of psychic (e.g., cognitive), physical and emotional functions may be a very important aspect not to be overlooked throughout the life cycle. Education for the "continuous care" of the elderly is almost a fundamental condition for mental health and well-being. This form of integrative-training, therefore, may be a great opportunity to safeguard the needs of the elderly so that they can face the senile age in a more positive way.

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