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EFFECTS OF RESISTANCE TRAINING ON COGNITIVE FUNCTIONS IN THE ELDERLY

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Abstract

The effects of 12-week resistance training on cognitive speed and memory were examined in active elderly people. Twelve elderly men (mean age 66.7 years) took part in the training programme; another 12 elderly people (mean age 67.4 years), not involved in training sessions, made the control (inactive) group. The training sessions were conducted thrice a week and consisted of a 7 to 10 minutes warm-up phase, 40-minute main phase and 2-5 minutes of post-exercise stretching. The comparison of results obtained at cognitive speed and memory tests conducted before and after the training period showed significant improvement in training group participants. The inactive group involved in the present study did not show any increase in cognitive functions. Pretest-posttest changes between groups could be observed also for the "sense of well-being" test. The pretest-posttest mean difference for the training group was significantly higher than for the control group. To analyze the long-term effects of resistance training the same variables were compared 6 months after the programme completion. In 6 months after the intervention subjects engaged in resistance training still had significantly greater muscular strength than the control group individuals. Significant differences between groups were found for memory testing.

The observed short-term and long-term improvements can be attributed to the added load of resistance exercises. The results suggest that repetitive sensory-motor processing together with motor learning activates the cognitive functions

Keywords: *resistance training, elderly people, cognitive function, memory, cognitive speed testing.*

Introduction

Aging is a natural phenomenon characterized by the loss of neurons and decrease in neurotransmitter release and physiological functions. The aging process is accompanied by deterioration of cognitive functions such as memory, attention, reaction time, and speed of information processing [*Van Boxtel M. et al., 1997*]. The neurotransmitters are known to play an important role in the processes of cognition, and deterioration of the transmitter system causes cognitive decrement in aging. The intensity of physiological functional capacity declines with advancing age even in healthy adults resulting in reduced capacity to perform physical tasks [*Tanaka H., Seals D., 1995*]. As demonstrated, exercise helps to prevent or reduce decline in cognitive functions. Reaction time and movement time experimental testing revealed that older adults always responded slower than younger individuals [*Spriduso W., 1975; 1980*].

Human brain tissue starts to lose cells in the third decade of life. Average losses are estimated at about 15% of cerebral cortex cells and 25% of cerebral white matter between the ages of 30 to 90. Both cognitive processes and motor responses slow as individuals get older [*Polich J., 1997*]. Long-term physical exercise results in adaptation of neuromuscular [*Narici M. et al., 1991*], metabolic [*Short K. et al., 2004*], cardiovascular [*Windecker S. et al., 2003*] and endocrine systems. It has also been reported that these adaptive changes occur also in older adults [*Hakkinen K. et al., 1996; Short K. et al., 2004*]. Studies have revealed that reaction time has been found to be shorter in

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physically active older adults than in inactive older ones [*Sherwood D., Seldar D., 1979; Spriduso W., 1980*]. Although physical activity and motor function measurements at the organism level have been extensively used to study effects of exercise on locomotion in the elderly, little investigation into the relationship between long-term exercise and behavioral or psychomotor functions and cognitive processing has been conducted.

Regular physical activity positively influences several factors that may prevent age related cerebral atherogenesis and sustain cognitive abilities [*Kraemer W. et al., 2002*]. As suggested, the increased cardiovascular fitness affects improvements in the plasticity of the ageing human brain [*Williams M. et al., 2007*]. Regardless of its importance, the effects of moderate exercise on the central nervous system of older adults are not fully understood.

The hypothesis that has guided the present study is that planned resistance training exerts beneficial influences, resulting in the improvement of cognitive functions in older individuals. We studied the effects of resistance training on cognitive processing through the Warwick-Edinburgh Mental Well-being Scale (WEMWBS) questionnaire [*Tennant R. et al., 2007*]; memory and cognitive speed test was also planned.

Hence, the aim of the present study was to investigate the effects of long-term exercise to the central information processing time in older adults and to compare cognitive functions between high fitness older individuals with low fitness ones. However, high intensity and/or heavy exercise aerobic high fitness training was excluded as inappropriate for older adults. Resistance training was chosen for the eldery individuals, and a training session was planned including certain type and number of exercises.

MATERIAL AND METHODS

Twelve people, who expressed interest in planned resistance training, were selected for the study. These volunteers, 12 men (mean age 66.7 years), were selected from elderly beginners, who attended the Sports and Fitness Center. There were no dropouts till the end of trial. Other 12 elderly men, sedentary participants not engaged in any physical training or fitness programmes, were included in the control group. All individuals of the control group were between 65 and 75 years of age; they were healthy, living independently, performing daily living activities without mobility aids.

We focused on the short- and long-term non-specific psychological effects such as well-being and memory in training group participants. The pretest and posttest procedure was identical for the training and control groups. The independent variables for the short-term evaluation were group membership (training group *versus* physically inactive participants) and time of measurement (pre- *versus* post-training). Dependent variables, which were assessed in the pre- and posttest procedure, were as follows: the psychological and physical well-being and memory parameters (free recall, recognition, and psychomotor speed). For the long-term evaluation we reassessed psychological variables and the muscular strength of the training and control groups six months after the study completion.

Testing was done 5 days before and 5 days after the 12-week training intervention. The training sessions were conducted thrice a week and consisted of a 7-l0 minutes warm-up followed by 8 resistance exercises on machines (2 leg knee extension, right knee flexion, left knee flexion, right arm curl, left arm curl, supine bench press, lat pull down, seated chest press).

Physical Strength: Hand dynamometry was used to assess the increase in muscular strength. Left and right hand grip was used to determine physical strength before and after training, as well as in every 4 weeks during the trial.

Memory and Cognitive Speed: We assessed the immediate and delayed free recall by administering a word list to the participants. Eight three-syllable words were given to the participants and they had to remember and write them down after 30 seconds on a clean sheet of paper. Delayed free recall test was conducted in 30 minutes. Immediate (in 30 seconds) and delayed (after 30 minutes) recognition tests were performed using the same word list, to which eight distracters (8 distracting words) were added. The participants had to mark the right ones. A subset of Wechsler adult intelligence scale (WAIS) test was planned and designed to assess the attention and information processing speed (Table 1) in older adults [*Kaufman A., Lichtenberger E., 1999*].

Psychological well-being: To assess psychological well-being Warwick-Edinburgh Mental Well-being Scale (WEMWBS) questionnaire [*Van Boxtel M. et al., 1997*] was used, and the response scores were presented in points (Table 2).

Table 1.

Wechsler adult intelligence scale subset for assessment of cognitive functions

Verbal Testing	Performance Testing
vocabulary	picture completion
arithmetic	picture arrangement
information	block design
comprehension	digit symbol-coding
digit span	matrix reasoning
similarities	figure weights

Planning and structure of training sessions: Training sessions were performed thrice a week for 12 weeks. The training session included 2 sets of 8 maneuvers (exercises) each. Each session lasted 50-60 minutes. One circuit consisted of 6 to 8 repetitions of the 8 maneuvers performed in 2 series with a maximum 2-minute rest between each set of maneuvers. In the first sessions (since week 1 to week 4), participants performed 50%-60% of the established one repetition maximum (1-RM). The training session started with warm-up (aerobics): seven minutes low intensity exercises (running, walking, cycling, light free weight exercises using 20% of usual workout weight, large and then small body part exercises, etc.). Pre-exercise stretching for 1-2 minutes was applied for muscles to be used during the workout (hamstrings, calves, quadriceps, chest). Exercises always started with large or multiple muscle groups (chest press, lat pull down, leg press, etc.), followed by small muscle group (biceps, triceps, deltoids and calves).

Post-exercise stretching for 2-5 minutes of mainly static stretches was applied, relaxing and elongating muscles that have become tight and short. Massage helped to shorten recovery time between workout sessions.

Table 2.

Warwick-Edinburgh Mental Well-being Scale

Statements	None of the time	Rarely	Some of the time	Often	All of the time
I've been feeling optimistic about the future	**1**	**2**	**3**	**4**	**5**
I've been feeling useful	**1**	**2**	**3**	**4**	**5**
I've been feeling relaxed	**1**	**2**	**3**	**4**	**5**
I've been feeling interested in other people	**1**	**2**	**3**	**4**	**5**
I've had energy to spare	**1**	**2**	**3**	**4**	**5**
I've been dealing with problems well	**1**	**2**	**3**	**4**	**5**
I've been thinking clearly	**1**	**2**	**3**	**4**	**5**
I've been feeling good about myself	**1**	**2**	**3**	**4**	**5**
I've been feeling close to other people	**1**	**2**	**3**	**4**	**5**
I've been feeling confident	**1**	**2**	**3**	**4**	**5**
I've been able to make up my own mind about things	**1**	**2**	**3**	**4**	**5**
I've been feeling loved	**1**	**2**	**3**	**4**	**5**
I've been interested in new things	**1**	**2**	**3**	**4**	**5**
I've been feeling cheerful	**1**	**2**	**3**	**4**	**5**

RESULTS

Main sessions for the training group included 2 sets of 8 maneuvers. The session started with a warm-up and ended with post-exercise stretching. Table 3 describes the dynamics of changes in physical loads for all 8 maneuvers used in the training program, as well as changes in muscular strength and endurance.

The comparison of cognitive pre- and posttest results showed a significant increase in the training group participants for the immediate and delayed free recall, whereas in individuals of the control group no significant differences were noted between the pre- and post-training period test results. The means and standard deviations of all cognitive pre- and posttest results in both training and control groups are shown in Tables 4 and 5.

In cognitive speed test verbal testing was aimed to assess the participant's comprehension of meanings and relations between the spoken or written expressive words. Simple arithmetic problems were offered to the group members to identify their mental alertness, focusing on concentration and arithmetic reasoning. The verbal testing measured also general knowledge of the participant, his capability to correctly understand simple information. Comprehension testing focused on the individual's social sense and conception of cultural values (for example, he was asked about the reaction to finding a bag full of money). Digit span test assessed the auditory short memory, attention and ability of concentration. Participants were given digit strings and asked to repeat them first forwards and then backwards. Verbal part of the subset also measured abstract reasoning and power of conceptualization in participants. They were given a set of apparently dissimilar objects to identify abstract similarities amongst them. The verbal test was assessed using 8-point scale (from 1 to 8 points).

Performance test scale has six sub-tests, which analyze different performing capabilities. Picture completion measures visual perception of participants asking them to complete a picture. Picture arrangement measures the ability to find out arrangements and analyze the sequential order. The participants were offered a set of pictures and asked to arrange them in a way of story-telling. Block design test measures non-verbal reasoning by requiring to organize blocks as shown on the given cards.

The colorful blocks design tells how much performing reasoning the individual has. In digit symbol coding test participants were shown a list of

TABLE 3.

The average loads for eight exercises, dynamics of muscle strength and endurance within the training period

Exercise	Initial maximum load	Load in 4 weeks	Load in 8 weeks	Load in 12 weeks
knee extension of 2 legs, *kg*	16	17	18	19
right knee flexion, *kg*	11	12	13	14
left knee flexion, *kg*	10	11	12	13
right arm curl, *kg*	9	10	11	12
left arm curl, *kg*	8	8.5	9.5	10.5
supine bench press, *kg*	15	17	18	19.5
lat pull down, *kg*	15	17	18	19
seated chest press, *kg*	16	18	19	20
left hand grip*, %	42	46	49	52
right hand grip, %	48	50	52	54
increase in muscle endurance**, %	-	16	28	34

NOTES: * - hand grip = handgrip strength/body mass;
** - muscle endurance was calculated by asking patients to sustain a load equivalent to 30% of the 1-RM as long as possible without changing the joint angle.

digits and symbols and immediately asked to write down the symbols that corresponded to a list of digits. Matrix reasoning is a visual-spatial problem solving. It usually involves a series of figures, in which there is a discernible pattern, with one figure in the series left blank. The problem was solved by determining, from an array of possibilities, what figure would complete the series or pattern. Figure weights measures quantitative and analytical reasoning. The participants used logic to determine equivalence of figures, using a drawing of a scale. Performance testing was assessed based on the test performance time. Student's *t*-test results revealed a significant pre/posttest increase only for the training group ($p<0.01$) (Table 5).

Pre/posttest changes between groups could be observed for the "sense of well-being" test. The pre/posttest mean difference for the training group was significantly higher than for the control group. The mean values and the standard deviation for the well-being test representing the sum of 14 credits (14 questions answered) for the both groups are presented as Table 6.

To analyze the long-term effects of resistance training we compared the same variables 6 months after the study training intervention. The results of

TABLE 4.

Memory test results, comparison within the training and control groups

Indices	Mean values and standard deviation by groups (in minutes)			
	training group		control group	
	pre-trial	post 12 weeks	pre-trial	post 12 weeks
associative test				
immediate	4.9±1.1	5.8±1.3	5.21.4±	5.3±1.4
delayed	4.3±1.1	5.4±1.2	4.93±1.8	5.0±2.0
recognition				
immediate	6.3±1.2	7.6±1.0	7.0±1.1	7.0±1.2
delayed	6.2±1.1	7.2±0.6	6.7±1.1	6.9±1.1

NOTE: * - statistically significant ($p<0.01$) difference between the groups.

TABLE 5.

Cognitive speed test results, comparison within the training and control groups

Cognitive speed test	Mean values and standard deviation by groups				*p*
	training group		control group		
	pre-trial	post 12 weeks	pre-trial	post 12 weeks	
verbal testing, *points*	4.2±0.7	6.9±0 62	4.0±0.73	3.7±1.0	<0.01
performance testing, *minutes*	35.2±14.5	41.9±13.5	38.1±11.9	40.2±12.4	<0.01*

NOTE: * - statistically significant ($p<0.01$) difference between the groups.

TABLE 6.

Findings for the well-being test in training and control groups

Index	Mean and standard deviation by group				*p*
	training group		control group		
	pre-trial	post 12 weeks	pre-trial	post 12 weeks	
well-being	35.7 ±5.3	52.6 ±4.9	36.8 ±4.8	38.0±4.6	$p<0.01$*

NOTE: * - statistically significant difference between the groups.

the test showed striking long-term effects: even 6 months after the intervention subjects, who were engaged in resistance training, had significantly greater muscular strength than participants of the control group. High mean differences were also found for memory testing: free recall and recognition. No significant changes were registered for psychological well-being in both groups.

Discussion

Elderly people enrolled in a 12-week resistance training program showed a significant increase in muscular strength directly after the intervention and six months later. The strength training protocol was adjusted by increasing resistance by 5-7% every four weeks of the study and included a familiarization session in the week prior to training. Improvement in muscular strength in the first few weeks of resistance training might be attributable to adaptation processes. In older individuals resistance training induces neurogenic adaptations, which contribute to the improvement in muscular strength. The presented study clearly identifies correlation between muscular strength and cognitive functions improvement in the elderly. Our study supports other research works, which found positive relationships between physical exercise and cognitive function [*Blomqist K., Danner F., 1986; Hill R. et al., 1993*]. During the training process older adults needed to control their movements and correct them following the educators instructions. In this way, the participants had to transform auditory, visual, and somatosensory inputs into motor outputs, recalling movement patterns. Repetitive sensory-motor processing together with motor learning activates the cognitive functions. Researchers showed motor skill learning to activate the process of synaptogenesis in cerebral cortex and cerebellum [*Kliem J. et al., 1996*]. The physical activity increases cell proliferation, cell survival and neurogenesis, increases levels of brain derived neurotrophic factors, increases resistance to brain insult and improves mental performance [*Cotman C., Berchtold N., 2002*].

The control group involved in the present study did not show any increase in cognitive functions, whereas the individuals involved in training sessions considerably improved test results after completion of the training. Upon the twelve weeks of training period part of the older adults continued to attend the Sports and Wellness Center for the following 6 or more months, but they continued training without special instructions or planning. However, the test conducted 6 months after the training intervention revealed improved results of cognitive functions evaluation in trained group compared to sedentary individuals. These short-term or long-term improvements can be attributed to the added physical exercise. The hypothetical mechanisms underlying the relation between physical activity and cognitive functioning in aged individuals are not finally established, and the molecular mechanisms of these effects remain unknown.

One of the above-mentioned hypothesis puts the emphasis on the nutritive influence of physical activity on the synaptic and neuronal functions. The second hypothesis is based on a correlation between aerobic capacity and cognitive performance in elderly persons with no known cognitive impairment. Moreover, the effects of aerobic exercise on cognition were shown to be enhanced when combined with strength or resistance training [*Dustman R. et al., 1994*]. Another hypothesis suggests that cognitive improvements are due to improved cardiovascular status. There is some research-based evidence [*Kemoun G. et al., 2010*] that physical activity lowers the risk of developing Alzheimer's disease, but further studies are needed to confirm this theory.

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