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Association of cognitive performance with the physical activity and body mass index in middle-aged and older rural inhabitants

D. ŁOJKO, W. PAŁYS, A. CZAJKOWSKA[1], K. WIECZOROWSKA-TOBIS[2], S. ŁUKASIK[3], K. GÓRNA[4], M. SOBIESKA[5], E. GAJEWSKA[5], A. SUWALSKA

Department of Adult Psychiatry, Poznan University of Medical Sciences, Poznan, Poland
[1]Family Physician Practice, AR-MED, Sokolniki, Poland
[2]Department of Palliative Medicine, University of Medical Sciences, Poznan, Poland
[3]Institute of Anthropology, Faculty of Biology, Adam Mickiewicz University, Poznan, Poland
[4]Department of Neurological and Psychiatric Nursing, Poznan University of Medical Sciences, Poznan, Poland
[5]Department of Physiotherapy, Poznan University of Medical Sciences, Poznan, Poland

Abstract. – OBJECTIVE: Last few decades have witnessed rapid ageing of the population. The prevalence of mild cognitive impairment and dementia is significantly higher in people aged 60 and over than in younger. The aim of the study was the assessment of the putative associations between physical activity and cognitive functioning in elderly inhabitants of a rural area.

PATIENTS AND METHODS: The participants underwent physical assessment, physical activity, cognitive functions, depression were assessed.

RESULTS: Highly active participants had better results in tests assessing psychomotor speed and in measuring attention and its flexibility comparing to groups of medium and low physical activity. Active people made fewer errors in the test measuring visual memory and new learning, and had significantly better results in the spatial-recognition memory test. Persons with symptoms of depression performed worse in visuospatial memory and working memory tests. Associations between physical activity and cognitive test results as well as association between body mass index and blood pressure and cognitive performance were observed.

CONCLUSIONS: The results of the study suggest an association between higher physical activity and better cognitive functioning in the field of working memory and visual and spatial-recognition, attention and attention flexibility. Symptoms of depression, hypertension and increased BMI may adversely affect cognitive performance in elderly.

Key Words:
Rural area, Cognitive function, Elderly, Physical activity.

Introduction

Last decades have witnessed rapid ageing of the population. The average life span has been continuously increasing, resulting in a growing percentage of the population aged over 60, and – consequently – an increased cost of medical care for those people. Above 60 the number of people with mild cognitive impairment grows rapidly, as does the incidence of dementia. Incidence of dementia estimates are increasing with age from 2 per 1000 in subjects aged 65-69 years to 74 per 1000 in subjects > 90 years old[1] and nearly half of the people aged 85 and older suffer from Alzheimer's disease in the United States[2]. Dementia is a chronic, progressive and as yet incurable disease. Therefore determination of the risk factors connected with worse cognitive functioning and contributing to the development of dementia seems to be of particular importance. Over the past decade, there has been an increasing focus on the influence of a number of lifestyle factors on the cognitive functioning of older adults. Numerous studies and metaanalyses in populations of elderly and middle aged people have indicated physical activity as an important factor improving cognitive functioning[3-6]. The mechanism of the influence of the physical activity on attention and executive functions has not been fully elucidated. The increased oxygen consumption and angiogenesis, and the neurotransmitters level and/or the regulation of neurotrophins, such as brain-derived neurotrophic agent (BDNF), insulin-like growth factor (IGF-1) and basic fibroblast growth factor (bFGF), have been proposed[7].

The aim of the study was to delineate the association between physical activity and cognitive functioning in older inhabitants of a rural area in

Corresponding Author: Dorota Łojko, MD; e-mail: lojko@ump.edu.pl

western Poland. Most studies have only examined selected cognitive domains, but nevertheless they have shown a positive impact of physical activity on memory[8], reaction time[9] and visuospatial skills[10]. In our study a wide range of cognitive tests was employed, both traditional paper-and-pencil tests and computerized versions of neuropsychological tasks.

Patients and Methods

The participants included 120 elderly inhabitants of a rural area in western part of Poland, who were recruited and assessed in their local General Practice in order as they were coming to their family doctor. An International Physical Activity Questionnaire (IPAQ)[11] was used to assess the level of their activity. The IPAQ enabled gathering information on the frequency and duration of their physical activity (intensive, moderate and walking). Three levels of physical activity are proposed: (1) Category 3: high, for individuals meeting one of the following 2 criteria: (a) vigorous-intensity activity on at least 3 days and accumulating at least 1500 MET-minutes/week OR (b) 7 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum of 3000 MET-minutes/week. (2). Category 2: moderate, for individuals meeting one of the following 3 criteria: (a) 3 or more days of vigorous activity of at least 20 minutes per day OR (b) 5 or more days of moderate-intensity activity or walking of at least 30 minutes per day OR (c) 5 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum of at least 600 MET-min/week. (3) Category 1: low, for individuals with the lowest level of physical activity. Those individuals who do not meet the criteria required for categories 2 or 3 are considered with low activity/inactive. The results are expressed as MET-min per week: MET level x minutes of activity/day x events (day) per week (C continuous Score)[12]. We also checked the BMI (body mass index), heart rate and blood pressure. In order to assess the mood we used the Beck Depression Inventory (BDI) – a 21-question multiple-choice self-report inventory, one of the most widely used instruments for measuring the severity of depression[12]. Participants underwent neuropsychological assessment lasting approximately 2 h. They completed the tests in a fixed order with a break half-way through. The Trail Making Test (TMT) and Stroop test[13,14] as well as selected tests from the Cambridge Automated Neuropsychological Test Battery (CANTAB; CeNeS Ltd, Cambridge, UK) – Spatial Working Memory (SWM), Pattern Recognition Memory (PRM), Spatial Span (SSP), Stocking of Cambridge (SOC), Paired Associated Learning (PAL)[15,16,17,18] were employed. Screenshots and detailed overviews of these tests are available online[19]; they have been described in our previous paper[20]. Brief descriptions of the tests are presented below.

*The Trail Making Test (TMT) c*onsists of two parts and is very sensitive to cerebral dysfunction. Part A of the test measures psychomotor speed. The results of part B reflect the ability to shift strategy and assess the executive function and visuospatial working memory[21]. Time is recorded in seconds. The *Stroop test* assesses directed attention and its flexibility. *Spatial Working Memory (SWM)* is a test of the subject's ability to retain spatial information and to manipulate remembered items in the working memory, which measures the working memory for spatial stimuli and requires the subject to use mnemonic information to work towards a goal. *Spatial Span (SSP)* is a test assessing working memory capacity. *Stockings of Cambridge Planning Task (SOC)* is a visual spatial planning test based on the Tower of London task[22,23]. *Paired Associates Learning* (PAL) test assesses visual memory and new learning. *Pattern Recognition Memory* (PRM) is a test of visual pattern recognition memory. *Spatial Recognition Memory* (SRM) is a test of visual spatial recognition.

The exclusion criteria in this study included dementia symptoms, a history of head trauma with loss of consciousness, substance abuse, epilepsy and severe somatic illnesses. The study was approved by the Ethics Committee of the Poznan University of Medical Sciences. The participants gave their written informed consent after being provided with a complete description of the study.

Statistical Analysis

Statistical analyses were carried out with Statistica version 10.0 for Windows. Between-group differences in the demographic characteristics, clinical factors and neuropsychological tests were assessed by *t*-student test (two-group comparisons) and analysis of variance ANOVA (comparisons among more than two groups). All results were expressed as the mean and standard deviation (SD). Statistical significance was set at $p < 0.05$ for all analyses. To examine the impact of physical activity on neurocognitive performance, correlations between activity data and neurocognitive test variables were calculated using Spearman's method.

Results

Our group of participants consisted of 120 persons (80 females and 40 males; mean age 60.1 ± 16.4 yrs), including 56 older persons (aged 65 and over) and 64 younger persons. The participants were divided into three groups based on their level of activity according to the results of the IPAQ. Eighty-six persons met the criteria for the high level of physical activity (H), 9 persons for the low level (L) and 25 participants fulfilled the criteria for the medium (M) level of physical activity. H- participants were significantly younger and scored less on the depression questionnaire but there were no differences in the body mass index (BMI).

These three groups were compared in terms of cognitive functions. Results are displayed in Table I. Group H had better results in TMT part A, assessing the psychomotor speed, and better results in both parts A and B of the Stroop Test (measuring directed attention and its flexibility), when compared to groups M and L. Active people made fewer errors in the PAL test and had significantly better results in the spatial recognition memory test (SRM). Twenty-one participants had symptoms of depression according to BDI (11 and more points). They performed significantly worse only in one of SRM subevaluations (SRM correct), had worse SSP span length results ($p = 0.006$) and made more errors in TMT part B ($p = 0.006$). The studied group included 25 overweight people and 30 obese persons. No significant differences between those subgroups and normal weight participants in terms of their cognitive functions were detected. They did not differ across such variables as age, years of education or symptoms of depression.

The associations between the activity levels and various aspects of cognitive functioning were also examined. The results are shown in Table II. Energy requirements of walking (both total and leisure) correlated negatively with the number of errors in PAL – a difficult test assessing visual memory and new learning. Energy requirements for walking as transportation correlated negatively with TMT B results. The age of the participants correlated with the number of errors in the Stroop test and the time taken to complete TMT part A. The number of correct trials in SRM correlated negatively with intense

Table I. Comparison of the results of cognitive tests. Values expressed as means ± standard deviation (SD).

Test	Levels (categories) of physical activity		
	High (H)	Moderate (M)	Low (L)
TMT A[1]	53.7 ± 36.6	93.2 ± 73.9	112.0 ± 60.2
TMT B	125.7 ± 75.1	160.4 ± 51.6	211.0 ± 52.8
TS A (time)[2]	30.5 ± 16.5	48.2 ± 47.8	44.4 ± 17.4
TS A (errors)	0.04 ± 0.20	0.17 ± 0.60	0.13 ± 0.35
TS B (time)3	85.0 ± 39.5	115.0 ± 86.3	76.8 ± 14.2
TS B (errors)[4]	2.9 ± 3.6	6.3 ± 9.8	10.4 ± 21.0
PAL Total errors[5]	33.9 ± 35.2	58.9 ± 53.4	34.1 ± 19.7
PAL Total errors (6 shapes)[5]	10.5 ± 12.1	18.8 ± 16.5	10.4 ± 3.9
PRM %correct	76.9 ± 15.4	72.2 ± 15.0	66.2 ± 15.9
SRM %correct[6]	74.9 ± 12.7	65.0 ± 13.8	65.6 ± 16.4
SOC Mean initial thinking time (5 moves)	8151.5 ± 6358.6	8797.4 ± 6684.7	5295.5 ± 5352.6
SOC Mean subsequent thinking time (5 moves)	5060.7 ± 7468.1	7203.4 ± 6063.4	3483.3 ± 4313.4
SOC Problem solving in min. moves	7.3 ± 2.1	6.8 ± 2.4	6.0 ± 3.0
SSP Span length	5.4 ± 6.0	4.3 ± 1.0	14.2 ± 29.4
SWM Between search errors	54.5 ± 19.2	62.0 ± 14.0	56.2 ± 26.3
SWM Strategy	37.9 ± 3.5	37.9 ± 3.4	35.9 ± 15.9

[1]Difference between H and L groups and between H and M groups, $p < 0.001$; [2]Difference between H and L groups, $p < 0.05$ and between H and M groups, $p < 0.01$; [3]Difference between H and M groups, $p < 0.05$; [4]Difference between H and L groups, $p < 0.01$ and between H and M, $p < 0.01$; [5]Difference between H and M groups, $p < 0.01$.

Table II. Correlations between level and type of physical activity and clinical factors and cognitive tests results.

	TMT A	TMT B	TS B [time]	TS B [no of errors]	PAL total errors	PAL total errors (6 shapes)	PRM % correct	SRM % correct	SOC mean initial	SOC problem solving	SSP span length	SW strategy
Walking MET min/week	0.12	0.26	-0.22	-0.06	-0.75*	-0.75*	0.52	0.39	0.54	0.55*	-0.37	- 0.57
Total number of active days	0.44	0.12	0.54	-0.01	0.20	0.24	-0.41	-0.07	0.30	-0.25	-0.39	-0.17
Walking MET (leisure)	0.39	0.65	-0.12	0.39	-0.64	-0.71*	0.13	0.51	0.55	0.33	-0.53	-0.25
Walking MET (transportation)	-0.28	-0.43*	-0.24	-0.03	-0.20	-0.12	0.11	-0.17	-0.09	0.30	-0.22	0.06
Intensive work activity	-0.25	-0.26	-0.10	-0.19	-0.00	0.04	0.08	-0.45*	-0.07	-0.03	0.23	-0.31
Sitting total minutes/week	-0.28	-0.19	-0.10	-0.28	-0.01	0.08	0.08	-0.11	-0.01	-0.18	-0.02	-0.14
Age	0.76*	0.68	0.47	0.72*	0.15	0.04	-0.53	0.53	0.44	-0.28	-0.49	0.35
Weight	0.27	-0.19	0.68	0.09	0.45	0.63	-0.47	-0.49	-0.06	-0.47*	0.26	0.20
Systolic blood pressure	0.58	0.34	0.54	0.40	0.24	0.12	-0.31	0.65	0.58	-0.06	-0.58	0.25
Diastolic blood pressure	0.26	0.35	0.43	0.00	-0.09	-0.10	-0.08	0.23	0.76*	0.30	-0.72*	-0.11
BMI	0.31	-0.09	0.61	0.42	0.61	0.66	-0.76*	-0.20	-0.13	-0.58	0.04	0.58

*significant at $p < 0.05$.

activity at work. Diastolic blood pressure correlated positively with one of the results of SOC (mean initial thinking time) and negatively with the span length in the SSP. BMI correlated negatively with the percentage of correct trials of the PRM. Energy requirements for overall walking correlated positively with SOC Problems solved in minimum moves, which means that the participants who walk more scored better in that test.

Discussion

Regular physical activity was described as a factor connected with a higher level of cognitive functioning[24]. Numerous studies have also highlighted the positive effects that exercise has on the aging brain: in clinical populations[25,26], healthy populations[27] and in animal studies[28] and on the other hand the worsening of cognitive function in obese[29]. In this study, physically active middle-aged and older rural inhabitants had better cognitive test results than less active participants. Associations between the duration and intensity of self-reported physical activity and cognitive functioning were also detected. Participants who reported a high level of activity had better results in the test assessing the psychomotor speed, directed attention and its flexibility when compared to the group of medium and low activity participants. Highly active people made fewer errors in the PAL test, which indicated that their visual memory was better. They also performed better in new learning tasks. Those with a high level of activity had significantly better results in the spatial recognition memory test (SRM) as well. These findings are consistent with the results of Brown et al[30] who have observed significant positive associations between higher intensity physical activity and the scores on the digit symbol, Rey Complex Figure Test copy and verbal fluency tests, as well as with reports of other authors[3,31]. In all those studies, individuals whose either self-reported or actigraphy-measured activity was higher had better results in the cognitive test in comparison with people who had a lower level of physical activity. Angevaren et al[3] have observed better performance on cognitive tasks while assessing speed, memory, mental flexibility as well as higher global cognition scores in individuals with a higher self-reported physical activity intensity, which is consistent with the results of Brown et al[30] who used actigraphy. We found correlations between physical activity and cognitive performance. High activity was associated with better results in tests of executive function, new learning, visuo-spatial working and recognition memory and directed attention and its flexibility as well as with better planning capacity (measured as problems solved in minimum moves in SOC). Our group included people with normal weight, overweight (20.8%) and with obesity (25%). We noticed fewer overweight people compared to the survey conducted in the eastern part of Poland[31]. Analysing the results of cognitive tests we did not find any differences between those three subgroups in cognitive performance, however a higher BMI was associated with worse results in the visual memory test. Hypertension is a risk factor for many diseases such diabetes, infarct, stroke, vascular dementia; high blood pressure is associated with lower cognitive functioning[33,34]. We noticed in our group that lower diastolic pressure was associated with better results of visuo-spatial subtest (SOC test) and working memory (SSP). According to Anson and Paran's review[35], mild hypertension at an old age may increase cognitive performance; besides, positive, adverse, or no relationships between cognitive performance and blood pressure have been reported. Depression is a common and underdiagnosed syndrome in elderly people, frequently associated with cognitive deficits, mainly in episodic memory and learning[26]. To assess the mood of the participants we employed the widely-used Beck Depression Inventory[12]. There were twenty-one persons who scored more than 11 points in the BDI. They performed worse than the remaining participants on several computerized tests as well as on the Stroop test. Depressed participants had a lower number of correct answers in the visual spatial recognition memory test (SRM). The results of the tests assessing working memory capacity and directed attention and its flexibility were also worse in this group. Our findings are consistent with most studies and appear to involve both explicit verbal and visual memory deficits in patients with depression as well as executive dysfunctions[37]. As depression is connected with a decreased psychomotor activity and it impacts volition-affected behaviours, it may also indirectly influence the level of physical activity. The mechanism(s) how exercises (physical activity, fitness) can influence the cognitive performance has not been fully elucidated yet. Certainly, intense physical activity can enhance cardiovascular (CV) health (by reducing blood pressure, lowering cholesterol levels)[38]. Hence, a healthier CV system facilitates an increased cerebral flow and perfusion as well as oxygen transport to the brain[4]. New data suggest that in order to achieve cognitive benefits induced by physical exercise, an increase in the cardiovascular fitness level must be maintained. An increase in the brain-derived-neurotrophic factor (BDNF) level associated with activity has been reported[39]. BDNF is known as a determinant of hippocampal neurogenesis, synaptic plasticity and neurotransmitter synthesis[40]. Higher levels of aerobic fitness have been associated with an increased hippocampal volume in 165 older non-demented adults, which translated to better memory function[41]. A positive impact of aerobic exercises on hippocampal volume has been established in humans and animals[42]. Individuals who did greater amount of exercise have demonstrated lower amyloid (which is associated with pathology of Alzheimer's disease) loading[43]. Some authors have pointed out that a common mechanism underlying the effects of exercise might be related to the inflammation, which can impair growth factor signaling both systemically and in the brain. By reducing peripheral risk factors such as diabetes, hypertension and cardiovascular disease, exercises help decrease brain dysfunction and neurodegeneration caused by the central inflammation processes connected with those systematic illnesses[43]. Circulating levels and brain uptake of insulin-like growth factor I (IGF-I) also increase with exercise. Trejo et al[44,45] has reported that blocking the entrance of IGF-I into the brain results in prevention of exercise-induced neuron proliferation in the dentate gyrus, suggesting that IGF-I also plays an essential role in neurogenesis. This evidence indicates that IGF-I plays an important role in the influence of exercise on cognition, BDNF levels, and neurogenesis. The exercise has been hypothesised to increase neurotransmitters (serotonin, norepinephrine) levels, and influence cognitive functioning by facilitating information processing[1,46] and improving mood. The positive effect of physical activity on cognitive functioning is probably mediated by the combination of numerous factors (some of which still remain unknown). We cannot forget about such "soft" factors as social and mental activities, which could also mediate this exercise-cognition association. We also do not yet know how much and what types of physical activity produce the most rapid and robust effects on cognitive functioning and brain. Nor do we know how long exercise effects last after cessation of training or how much exercise is needed to reinstate previously observed benefits. The benefits of physical exercise or physical activities promoting brain and cognitive vitality well into older adulthood have been well documented. Now, more intervention studies are needed to address questions related to the benefits of exercise and mechanisms involved. We would like underline that this study includes self-reported activity data and not assesses duration, intensity, and frequency of activities. The specificity of our studied group ensues from the fact that most of the activity of the rural area inhabitants, reported as physical activity in the questionnaire, is connected with their daily routines. For many of our respondents, riding a bike or walking is simply the only available way of moving from place to place, while working in the garden is aimed at production of food rather than being a leisure activity. The life style and the place of residence greatly affect our physical activity patterns and preferred recreation types. A city inhabitant doing sedentary work will choose riding a bike as a recreational activity. However, premises underlying that choice will be entirely different than in the case of a bicycle ride taken by a rural inhabitant to the nearest grocery store located several kilometers away or to the place of work.

This is a preliminary report. The research is still going on: in subsequent studies covering larger groups of participants a greater number of social, demographic, medical and other confounding factors will be taken into account. We did not analyse the impact of diabetes (direct and mediated by depressive symptoms), movement disabilities or some life-style factors (i.e. drinking behaviours, smoking) on cognitive function and physical activity. On the other hand, to our knowledge, this is the first paper concerning the association of physical activity and cognitive functions in Polish elderly inhabitants of a rural area, employing such a wide cognitive tests battery. Changing life-style factors is safe and inexpensive and we already have got results how changing life-style can reduce for example cardiovascular risk factors[47], therefore further studies are needed to elucidate how changing in physical activity can improve cognitive functioning and reduce the likelihood of development of dementia processes. We are in need to conduct Polish studies on physical activity in elderly inhabitants of Poland, taking into account social, cultural and economic differences between the rural and urban areas and elderly populations living there (referred to in the surveys of residents of a capital city and of the countryside).

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Conflict of Interest

The Authors declare that there are no conflicts of interest.

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