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REVIEW PAPER

The impact of physical activity on the cognitive fitness of the elderly – a review

Anna Marszałek [1], Tadeusz Kasperczyk [2], Robert Walaszek [3], Katarzyna Burdacka [3]

[1] Public Elementary School of Friends of Catholic Schools Association in Hucisko-Pewelka, Hucisko, Poland
[2] Department of Aesthetic Cosmetology of the University of Physical Education in Kraków, Kraków, Poland
[3] Department of Recreology and Biological Regeneration of the University of Physical Education in Kraków, Kraków, Poland

ABSTRACT

Introduction and aim. The issues of humans' ageing are more and more frequently addressed in the relevant literature. Most commonly, people follow three ageing trajectories: a normal one, disease-affected one, and a healthy one. The purpose of this article is to present a relationship between physical activity and occurrence of cognitive function impairment in the elderly.

Material and methods. This paper is a narrative review. Based on a literature search, various forms of physical activity are presented, as well as the effects of physical activity on mitigation of cognitive disorders in the elderly. The following databases were used: Web of Science, PubMed, Google Scholar.

Analysis of the literature. One of the most important factors that promote healthy ageing is regular physical activity. Many studies and publications have addressed this issue. The relationships between physical activity and cognitive fitness have been less studied.

Conclusion. The results of the studies presented in this article may form the basis for more in-depth analyses and, in a long-term perspective, for the development of optimal preventive and therapeutic strategies using broadly understood physical activity to maintain cognitive fitness of the elderly.

Keywords. cognitive functions, physical activity, old age

Introduction

A worsening of cognitive fitness in the old age is a common problem and it is associated with the loss of the ability to perform daily activities. Cognitive functions are often defined as higher mental function including such processes as perception, learning new information, visual-spatial awareness, attention, thinking, language functions, memory and executive functions. Age-related cognitive impairment is not yet well understood, but many studies point to such changes as a reduction in both grey and white matter volumes and to changes in neurotransmitter levels, which may contribute to the observed cognitive deficits.[1] It should be underlined that there is no established pattern of cognitive impairment severity that would correspond to physiological ageing. It is generally accepted that presence of mild cognitive impairment (MCI) is an intermediate condition between cognitive function changes in the course of normal ageing and dementia.

Initially, the MCI concept was associated only with Alzheimer's disease (AD) and memory deficits. In order to explain the earliest stages of symptomatic AD, the MCI criteria were developed in 1999 by the experts of the Mayo Clinic. These criteria included the following: subjective patient's complaints on cognitive function impairment, the presence of cognitive dysfunctions

Corresponding author: Robert Walaszek, e-mail: robertwalaszek63@gmail.com

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confirmed by objective psychometric testing, the absence of any changes in daily functioning and the absence of dementia.[2]

It was not until the works of an international group of experts – the International Working Group on Mild Cognitive Impairment – undertaken in 2003 during the Key Symposium in Stockholm, when a broader understanding of the MCI concept emerged.[3] According to the adopted concept, two subtypes of mild cognitive impairment have been identified: an amnestic one and a non-amnestic one. The amnestic subtype (aMCI) is characterised by a memory function impairment that, however clinically relevant, does not meet the criteria of dementia diagnosis. On the other hand, the non-amnestic subtype (naMCI) can be described as a minor deterioration of functions not related to memory, such as concentration of attention, language-related and visual-spatial functions (Fig. 1).[4]

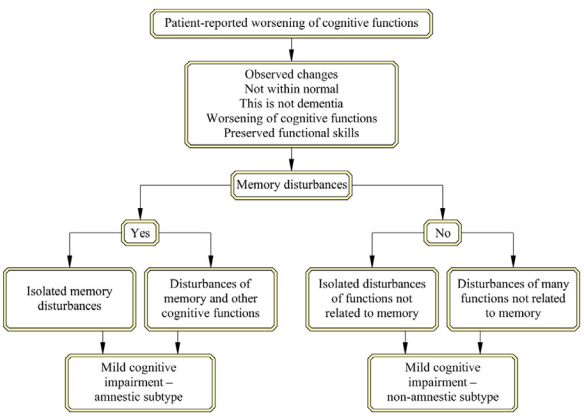

Fig. 1. Diagnostic algorithms for the diagnosis of amnestic and non-amnestic mild cognitive impairment[5]

According to the most recent data, the incidence MCI is 6.7%, 8.4%, 10.1%, 14.8%, and 25.2% among people aged 60 to 64 years, 65 to 69 years, 70 to 74 years, 75 to 79 years, and 80 to 84 years, respectively.[6] Neurodegenerative diseases, cerebral ischaemia, and mental disorders are listed among the aetiological factors of MCI.[3] The study by Solé -Padullés et al. on the relationship between cognitive reserves and the structural and functional brain condition, has shown that there is an inverse relationship between healthy and pathological brain ageing and cognitive reserves. In the group of healthy people, higher reserves were associated with a larger brain volume and a lower activity of the nervous tissue during cognitive task execution. The authors have suggested that this was due to more effective function of neuronal networks in this group. In contrast, in the group of people with the MCI diagnosis, higher levels of cognitive reserves were associated with lower brain volumes and a higher activity of the nervous tissue during cognitive tasks, which was indicative of a more advanced nervous system pathology.

When considering clinical factors related to cognitive function worsening, it is also worthwhile to note the presence of mood disorders. Late-life depression (LLD) is considered to be the most common mental problem affecting people in their old age.[8] Therefore, quality of life is an important issue, which is the resultant of emotional state, physical health and functional fitness in everyday life, especially in relation to the elderly.[9] However, the relevant literature is not clear as far as the proportion of the elderly affected by depression: some authors estimate it to be about 7%[10], while others report that as many as 65% of people older than 65 years of age experience depressed mood and other symptoms of a depressive syndrome.[11] Gao et.al. together with their team have reviewed the studies whose aim was to check whether the presence of depressive symptoms increases the risk of MCI occurrence. According to the results of their analysis, as compared to healthy people, depressive patients have an increased risk of cognitive impairment development.[12] An analysis performed by Rock et al., in turn, have shown that cognitive function deficits, and particular deficits of executive functions, memory and attention, are frequently present during depressive episodes, and some of them (this pertains to executive functions and attention) persist despite the resolution of the other depressive symptoms. Based on this observation, the authors have concluded that cognitive function impairment should be considered a core feature of the depressive disorder, not less important than, for example, depressed mood.[13]

Despite the ambiguity associated with the changes in definition, as well as the variation of the aetiology and symptoms, the assessment of cognitive function status in the mild cognitive impairment is crucial for the diagnostic and preventive process.[14]

As far as possible actions are concerned, there are currently no recommendations that would advise a medical treatment of MCI.[2] Placebo-controlled clinical studies have shown no significant reduction of the rate of progression to dementia in patients with MCI who were treated with the products used in the treatment of Alzheimer's disease.[15]

To date, no medical treatment has been approved by the European Medicines Agency, the US Food and Drug Administration or the Pharmaceutical and Medical devices Agency, either.[16] Therefore the researchers focus currently on the search for alternative forms of therapy. Among the non-medical methods that give the most positive clinical effects, appropriately dosed physical activity is mentioned in the first place.

Aim

Therefore, the aim of this study is to present the impact of regular physical activity of the elderly on their cognitive functions.

Material and methods

This work is a narrative review. It was written based on a document analysis method, with use of quantitative and qualitative techniques. The review includes Polish and international scientific literature collected in such databases as Web of Science, PubMed, Google Scholar. This article presents the results of studies assessing the effects of physical activity on the cognitive function of the elderly conducted between 1999 and 2021, including, in particular, international publications. The articles were analysed with particular regard to the preventive and therapeutic aspects of the use of adequately dosed regular physical activity, to the types of therapies used and to the documented effects of the therapy with physical exercise. After the search of the above mentioned databases, 86 articles were selected that have met the objective of this work, and 52 works out of these 86 were further selected for a more detailed analysis. These 52 works have met high methodology requirements and at the same time they have met the following inclusion criteria:

1. They presented complex neurophysiological background of the ageing process.
2. They presented different forms of physical activity and its effects on mitigation of cognitive disorders in the elderly.
3. They used some indices to assess the effects of various physical activity regimens in the elderly.
4. They showed differences in exercise execution, movement planning and processing of sensory information in the advanced-age population.
5. They documented how enhanced physical activity improves the patterns of active behaviour of the elderly.

Irrelevant articles, systematic reviews, meta-analyses and case studies were excluded from the analysis. The following keywords were used during the literature search: old age, physical activity, cognitive functions.

Analysis of the literature

Physical activity and cognitive functions

According to the WHO, mental health means well-being, when a person executes their potential and is able to cope with a variety of life situations, as well as to participate in the social life.[17] Basic cognitive and social skills, the ability to recognise, demonstrate and shape one's own emotions, and to sympathise with others, flexibility and ability to cope with adverse situations in life, the ability to perform functions in social roles, as well as a harmonious relationship between the body and mind are important components of mental health.[18] The studies show that intended and conscious physical activity has an effect on mental well-being, as the aim of physical fitness is a positive effect on health resulting in a low risk of disease occurrence, which in line with the health-related fitness (H-RF) concept. Achievements in this area should in turn encourage engagement in daily tasks with adequate energy and provide satisfaction from participation in selected forms of physical activity. Thus this concept emphasizes promotion of health and active lifestyles, and motor fitness is a factor that allows achievement of perfect health and optimal quality of life.[19]

Different "healthy doses" of physical exercise are recommended for different age ranges. For people older than 65 years, the WHO (Global Strategy 2010) recommends regular physical exercise of moderate intensity (4 to 6 Met) for 150 minutes per week or high intensity exercise (above 6 Met) for 75 minutes per week. A Canadian expert team accepted the following recommendations as useful for health maintenance and improvement:[20]

a. 60 minutes daily for light efforts (e.g., walking, gardening, stretching) that cause such symptoms as feeling of warmth and a slight acceleration of breathing,
b. 30 to 60 minutes daily for moderate efforts (e.g., cycling, swimming, dancing) that cause such symptoms as increased warmth and a marked acceleration of breathing,
c. 20 to 30 minutes daily for intense efforts (e.g., aerobic, jogging, fast swimming) that result in sweating and shortness of breath.

For the elderly, Kasperczyk has suggested a slightly different attitude than the pre-defined recommendations based on strict physiological criteria. According to this author, it would be preferable to define tasks/objectives of physical activity and leave the form and dose of movement open to specific tasks. These tasks/objectives include the following:[21]

a. to assure postural muscle strength at the "minimum muscle strength" level, as recommended by Kraus and Weber,
b. to keep the physical condition at such a level that efforts of increased intensity (e.g. climbing stairs, running up, etc.) do not produce significant shortness of breath,
c. to practice exercises requiring complex movement coordination, including balance exercises, stretching and relaxation.

Kasperczyk points out that everybody should choose the form and intensity of their physical activity on an individual basis so that the above health-related goals of physical activity are achieved. It is also worth emphasizing that adequate physical effort contributes to the so-called healthy ageing phenomenon.[21]

According to Anderson, this is due to the fact that regular physical exercises regulate the stimulation of the nervous system, which has been proven in studies that emphasize the neuroprotective properties of motion.[22] Many studies evaluating brain activity have shown a significant impact of physical exercise on the cognitive processes at the molecular level, mainly by releasing

neurotrophins in the central nervous system. Research conducted by Park and Poo has confirmed that the key molecule involved in learning and memory is the brain derived neurotrophic factor (BDNF) whose production is increasing as a result of physical exercise.[23] BDNF synthesis occurs mainly in the nervous cells, connective tissue cells and immune system cells – T and B cells and granulocytes. The highest BDNF levels are observed in the cerebellum, hippocampus and amygdala. Additionally, BDNF increases the number of synapses and enhances axonal branches in the cerebral cortex.[24] According to Angelica et al., another factor mediating the production of BDNF in the brain as a result of physical exercise is the growth hormone - insulin like growth factor-1 axis (GH/ IGF-1 axis). Physical activity increases the amount of circulating GH, which is the main driver of IGF-1 production. During the physical effort, there is an increase of IGF-1 levels both in the brain and in the peripheral blood, which leads to increased proliferation and differentiation of the neurones, thereby improving concentration and short-term memory.[25] On the other hand, based on their research, Liu et al. have documented that besides BDNF and the GH–IGF-1 axis also the fibroblast growth factor (FGF) is involved in mechanisms mediating the effect of physical exercise on normal neurogenesis.[26] It should be pointed out that BDNF, IGF-1 and FGF are responsible not only for neurogenesis but also for angiogenesis, which, according to Ide and Secher, affects compensatory plasticity whose functional manifestation is normalisation of blood flow and brain vascularisation, contributing to better supply of oxygen and nutrients to the brain.[27] By using angiographic MR techniques, more small cerebral vessels were found in active elderly people, as compared to their peers leading a sedentary lifestyle.[28] It should be pointed out that one of the proposed mechanisms of the favourable effects of physical activity on the cognitive processes is the effect of BDNF on cellular energy production. According to Gomez-Pinilla and Hilmann, this compound activates many energy systems in the brain, through which it affects synaptic potentials involved in processing of information important for cognitive function formation. This pertains in particular to the pathways responsible for the maintenance of cell energy homoeostasis. Both physical effort and diet translate into the energy balance of the body and, at the cellular level, they influence energy production in the mitochondria. These processes are important to maintain appropriate neuronal excitability and synaptic functions.[29]

A review of the studies evaluating the impact of regular physical activity on the mitigation of cognitive disorders in the elderly

The relevant literature contains many reports on the role of physical activity in prevention of progression of mild cognitive impairment in the elderly. The purpose of a study by Heyn et al. was to assess the effect of various physical activities (such as isotonic exercises or aerobic activities in the form of dancing or indoor cycling) on mild cognitive impairment in people aged 66 to 91 years. A single training session lasted 45 minutes on average and the sessions were repeated at a frequency of 1 to 6 times per week, and the entire study duration was 112 weeks. The results of this study confirmed the positive impact of regular physical exercise on memory and attention improvement.[30]

Also Kramer et al. conducted studies on the effect of physical activity on cognitive functions in the elderly. The subjects were divided into three age groups: 55 to 65 years, 66 to 70 years and 71 years and over. Cognitive tests were divided into four groups: execution, cognitive control, spatial orientation, and speed. The authors have shown that the group aged 66-70 years practising a mixed (resistance and aerobic) training achieved better results in each test, as compared to persons who performed only aerobic exercises.[31]

Antunes et al. have carried out a study that included women aged 60 to 70 years leading a sedentary lifestyle. The researchers have shown that women participating 3 times per week in a 6-month aerobic training program complemented with stretching exercises (23 women) have achieved better results on the Geriatric Depression Scale (GDS) than those who practised recreational dancing and handicraft activities (17 women). The aerobic training resulted in an increase in VO_2 that correlated with increased cognitive performance, in the areas of attention concentration, operational and episodic memory, visual-spatial coordination or response speed shown in the tests, among others.[32]

Another study to assess the impact of aerobic exercises on the cognitive fitness in the elderly people affected by mild cognitive impairment was conducted by Baker et.al. The exercises took place 4 times per week for 6 months. The subjects were divided into experimental and control groups. The control group practised stretching exercises not exceeding 50% of the heart rate reserve, while the experimental group practised aerobic exercise with exercise intensity at the level of 75% to 85% of this reserve - this group achieved an 11% increase in VO_2 after program completion. The results of the tests assessing cognitive fitness showed an improvement in cognitive function in the area of selective attention along with increasing VO_2 (more pronounced in women) in the study group.[33]

A positive impact of aerobic training involving regular walks on women aged between 70 and 80 years suffering from mild cognitive disorders has also been confirmed by a study conducted by Davis et al.[34]

Liu-Ambrose et al. presented an interesting assumption in their study. They randomised 155 women

aged 65 to 75 years into three groups. Group assignment was based on exercise type: endurance training once per week, endurance training twice per week, training of balance and muscle tone regulation twice per week. The subjects participated in the training for 12 months. The endurance training included strength exercises for different muscle groups performed in two series of 6 to 8 repetitions (squats, lunges). The training of balance and muscle tone regulation included stretching exercises, relaxation techniques, tai chi-derived positions and one-leg stance. Performance of cognitive executive functions was assessed with the Stroop test, the trail making test (A and B), and the digit repetition test (forward and backward). The study has shown that in the elderly women endurance training improves cognitive function in the area of attention selectivity, along with muscle strength enhancement. No such changes have been observed as a result of balance training and muscle tone regulating exercises.[35]

A study by Colcombe et al. is also worth mentioning. By using magnetic resonance imaging (MRI) they have demonstrated an increase in the frontal and temporal lobe cortex grey matter volume in subjects aged 60 to 79 years participating in a 6-month aerobic exercise program. No such changes have been found in the control group (consisting of peers of the experimental group members) who practised dynamic and stretching exercises at that time. The program of the exercises consisted of one-hour marches three times per week. Along with the structural changes induced by physical activity, a significant improvement of cognitive functions has also been observed.[36] Also Burdette et al., by using MRI scans, have demonstrated that there was an enhancement of functional connections between particular brain regions, especially between the hippocampus and the cortex of the anterior cingulate gyrus in people aged 70 to 85 years after 4 months of march training.[37]

The results of an experiment by Rehfeld et al. provided important information for even better understanding of the changes in the central nervous system. In people aged 67-68 years with mild cognitive impairment, they assessed the differences in the effects of aerobic and various types of dance on an increase of the hippocampus volume. These activities were conducted for 18 months, the program based on aerobic was completed by 12 persons and the dance program – by 14 people. During the first 6 months, the sessions were held 2 times per week, then once a week, 90 minutes each. Only in the dance group, a significant increase in the volume of the right hippocampus was observed. Both dance and fitness activities caused an increase in the volume of the left hippocampus, with a larger area of this increase in the group of dancers. Only in dancers, the MRI scans showed an increase in the volume of the dentate gyrus where neurogenesis occurs.[38] This relationship has also been confirmed in a study by Mueller et al.[39]

In addition to aerobic exercise and dancing used in the training of the elderly, also yoga deserves some attention. Eyre et al. have compared a memory training and participation in yoga classes with respect to their effect on cognitive function in people aged more than 55 years with MCI. Both programs lasted 12 weeks and involved 1 hour of exercises per week, along with a recommendation to work at home. 39 people were assigned to the yoga group, and 42 people – to the memory training group. The results of the study have shown a greater improvement of both the executive functions and mood in the group that practised yoga.[40] Similar benefits have been obtained in a study by Tew et al.[41]

Among many issues raised by the authors of this work, it is important to remember that not every type of exercise has the same effect on brain structures. As reported by Ploughman, a very intensive and prolonged physical effort results in increased secretion of glucocorticoids, including cortisol that reduces BDNF levels. Decreased secretion of BDNF results in neurogenesis inhibition, decreased brain neuroplasticity, increased apoptosis and neurodegenerative processes in the limbic region of the brain, especially in the hippocampus.[42] Moreover, according to Gallaway et al. it should be noted that the effectiveness of reducing the risk of MCI development depends not only on the optimal training selection but also on the individual's cardiopulmonary performance, age, initial cognitive fitness, medication taken and social environment.[43]

Ageing is a natural long-term process leading to disturbances of the physiological functions of the body. Senile changes are characterised by systematic deterioration of health – not only of the physical health but also of the emotional and social well-being, which leads to a reduction of functional reserves of the individual organs and of the organism as a whole.[44] In this context, it seems necessary to seek new models of life based on popularisation of a healthy lifestyle combined with physical activity.[46] According to Grimm et al., regular physical exercises have an impact on preservation of fitness, independence and autonomy in execution of daily activities, and are an important element of favourable ageing, which, according to Han and Ko, means the best possible course of this process, free from pathology, positively shaped by external conditions, with minimal physiological, psychological and social deficits attributable to the calendar age.[46,47] As reported by Rizzuto et al., the level of physical activity is decreasing with age, both in women and in men.[48] This is also confirmed by the reports of Hama et al.[49] This trend is observed worldwide.[50]

It is therefore essential to raise awareness of the importance of regular physical activity among people as young as in their 50s. Programs that motivate the elder-

ly to take up physical activity should be implemented on a wider scale. A shift from a sedentary to an active lifestyle is necessary to maintain cognitive fitness, which is essential for maintenance of the quality of life at a satisfactory level, defined as physical, mental and social well-being, and not merely absence of a disease.[51] This correlates significantly with assumptions of Rembowski who claimed that: *"Activity is needed at any age, not excluding the late years of life. So old people are pleased with themselves if they undertake activities that replace their lost primary role. Satisfaction at this age is directly associated with maintenance of activity in middle age."*[52]

Conclusion

In the light of the above considerations based on a review of the available literature, it may be concluded that such promising reports, demonstrating a positive relationship between physical activity and mental health, should form the basis for more in-depth research and, in a long-term perspective, for the development of optimal therapeutic and prophylactic strategies in the discussed area.

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Author contributions

Conceptualisation, A.M., T.K.; Writing – Original Draft Preparation, A.M., T.K. and R.W; Writing – Review & Editing, A.M., T.K., R.W. and K.B.

Conflict of interest

The authors declare no conflict of interest.

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