THE IMPACT OF AEROBIC TRAINING FOR AGING OF THE CENTRAL NERVOUS SYSTEM

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Abstract:
During the aging the human brain undergoes morphological changes in neurons, synaptic plasticity and cell dehydration in main brain structures as hippocampus and prefrontal cortex. It effects on cognitive abilities as short and long- term memory, learning abilities and has an impact on the executive functions. In many studies conducted on lab animals and humans has been proved that the best alternative to decrease the aging affects is an aerobic training. The physical exercises could improve the blood circulation and learning motor skills causing the increase in the number of synapses.

There is a lot of publications referring to the impact of physical exercises on the central nervous system and its aging. For ethical reasons, described in these experiments, mostly been performed with animals [Blumenthal et al., 1991; Hill, Storandt and O'Malley, 1993; Black, Isaacs, Anderson, Alcantra and Greenough, 1990]. During these pioneer experiments, they have detected the growth of capillaries in the cerebellum of rats trained in wheels (treadmill). Whereas Fordyce and Farrar (1991) have noticed that an increased efficiency of aerobic training, acquired during running, could increase the choline demand in the cortex and dopaminergic receptors density in older rat brains. Increasing the expression of brain-derived neurotrophic factor (BDNF) gene was noted by Neeper, Gomez, Choi and Cotman (1995). Improvement the number of neurons in mouse brains was noticed as well [van Praag, Kempermann and Cage, 1999]. The probability that in humans during the same type of physical exercises will occur the similar cell changes and neurochemical processes contributing the perception, cognitive and motor functions improvement seems to be very high. W.W. Spirduso has created the comparison of tennis players and runners to people leading sedentary life and it was confirmed that their reaction time was shorter and similar to young not active adults [Kołodziejczyk, 2007]. Mentioned experiments were the inspiration to further studies on people, which will be described in this article.

The aim of following work is review and systematization of recent publications about the role of physical exercises, especially aerobic training, in aging of central nervous system (the brain) and synaptic plasticity in neurons.

AGING OF CENTRAL NERVOUS SYSTEM

In the moment of birth, the organism stars to develop and growing old in the same time. The plasticity phenomena, especially the nervous system plasticity decreases with aging. It is proved by fact that organism is getting more susceptible to neurotoxins and cannot effectively fight against their negative influence. The aging of the nervous system could occur physiological as well as pathological. „*In the normal aging of the nervous system revealed no dramatic changes in structure, and its result is to slow down and deterioration of quality nervous system function in substantially healthy subjects. However, changes as a result of pathological processes lead to the development of various clinical syndromes, of which the most common are so-called dementia*" – Niewiadomska claims [Górska, Grabowska, Zagrodzka, 2005]. The most common example of pathological dementia is Alzheimer disease. Disease processes are usually irreversible. Followed by dying neurons arise pathological structures. These changes interfere with cognitive functions of the person concerned [Mountain, Grabowska, Zagrodzka, 2005]. *"Currently, most of the measurement data obtained in humans and apes shows that the number of nerve cells in the brain does not decrease significantly with age*" [Mountain, Grabowska, Zagrodzka, 2005].

AGING PROCESSES IN THE BRAIN – MACROSCOPIC CHANGES

About 50 years starts shrinking of brain tissue. This leads to a reduction in cortex layers' thickness, cortical atrophy of the cerebral cortex and degeneration of the myelin sheath (Piechota, 2014). " *In this age, the average weight of brain is decreasing from 1,4 kg in the age of 25 years to 1,2 kg"*(Górska, Grabowska, Zagrodzka, 2005). "*However, in contrast to the widely circulating view, the brain shrinkage does not mean the accelerated loss of nerve cells. It is the result of deprivation of water in nerve cells. The most striking change appears in the brain with aging is loss of the water content in nerve cells. It should be noted that this applies only to the cells, while in the intercellular space the water content does not change. Therefore, about 50 years of age, hydrated mass of brain tissue begins to decrease „*[Górska, Grabowska, Zagrodzka, 2005]. The studies found a decrease in the entire neuron, the reduction of dendritic spines (mainly in the prefrontal area of old monkeys; Peters et al., 2008, Dumitriu, 2010), and synapses, and changes the branching of dendritic trees. A similar phenomenon was observed in aging laboratory animals. Reduction the water content in nerve cells causes increase in protein content, which is the cause of changes in functioning of dehydrated neurons.

The brain is diversified in terms susceptibility to the above-described changes. And so, around the cerebral cortex, which contain a large number of small granule cells (parietal and occipital cortex) lose less water from areas containing mainly large pyramidal cells (eg. the frontal cortex, motor cortex). "*The shrinkage of neural tissue causes broadening of the spaces (grooves) between brain gyri and the expansion of the intracellular compartments of the brain, called the space. Usually males are predisposed to earlier changes*" - [Mountain, Grabowska, Zagrodzka, 2005].

AGING PROCESSES IN THE BRAIN – MICROSCOPIC CHANGES

Recent studies suggest that over the years the number of neurons in the brain does not change significantly. Each day die about 10 000 neurons of the cerebral cortex. As well as macroscopic changes in the brain, microscopic changes take place with different intensity in different regions of the brain. In the process of physiological aging brain, neuronal death is not observed in the brainstem, and when it they, it dies very small number of them. There occurs a noticeable reduced ability to neurogenesis [Piechota, 2014]. The same is observed in the substantia nigra. On the other hand, when a person is suffering from Parkinson's disease, there is a significant degeneration of substantia nigra cells, which are responsible for producing dopamine. Rapidly aging the cerebellum containing Purkinje cells This is related to the loss of motor function and coordination of movement. Also die quickly neurons in the frontal lobes, which causes deterioration of cognitive function. "*Perhaps this decline is associated with reduced cholinergic innervation the frontal lobes' from the basal forebrain* *area where the majority of cholinergic neurons of the brain is located. With age, deterioration occurs in the brain cholinergic projection, which is caused by loss of cholinergic neurons neurotransmitter phenotype* "[Mountain, Grabowska, Zagrodzka, 2005]. They lose the ability to synthesize acetylcholine – "... *recently there are reports which show that in the natural aging process, the cholinergic neurons do not undergo atrophy*..." [Mountain, Grabowska, Zagrodzka, 2005]. Probably the deterioration of cholinergic projection in the brain is associated with the disappearance of the so-called neurotransmitter phenotype of cholinergic neurons. The neurons lose their ability to synthesis of acetylcholine. This is confirmed by researches on the effects of growth factor (NGF) administration for the morphology of cholinergic neurons in aged rats. From this it is concluded that the administration of NGF can prevent the loss of ability to synthesize acetylcholine by nerve cells aging [Mountain, Grabowska, Zagrodzka, 2005].

The Bloss'es work indicates a loss of plasticity in the hippocampus, the structure responsible for learning and memory. This happens mainly due to the degeneration of thin dendritic spines. In experiments involving stressed animals, the apical dendrites regeneration of apical dendrites was followed by increase in number of branches after the cessation of stress stimulus. In old individuals, mentioned changes were irreversible [Bloss, 2011].

There was also a decrease in the number of synaptic vesicles: synaptophysin and SNAP-25, a factor which is considered to be the direct cause of the reduced ability to learn.

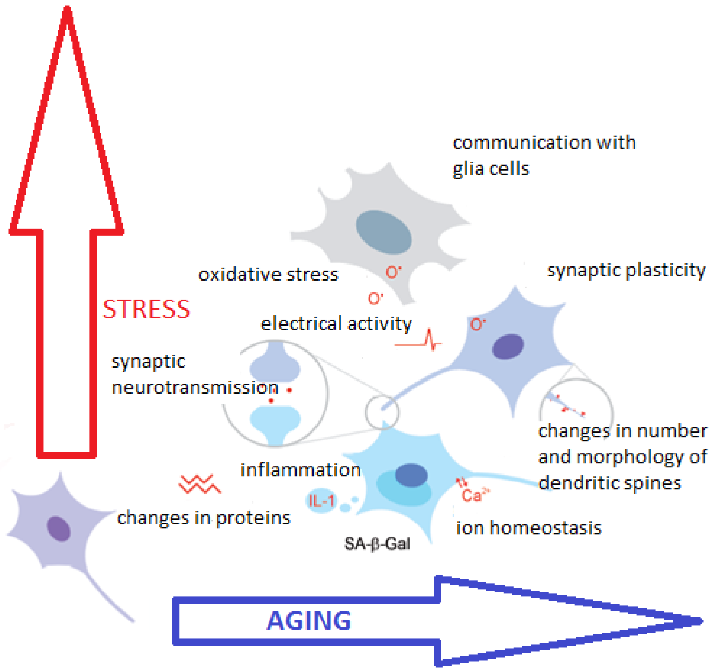

Figure 1. The picture shows the impact of aging for structural changes in neurons. Based on: Piechota M., Sunderland P., 2014. *Starzenie neuronów*. Postępy Biochemii 60 (2), 177-186.

THE IMPACT OF PHYSICAL TRAINING FOR HUMAN ORGANISM

The effect of physical activity to increase strength, endurance and muscular performance is well documented by numerous scientific studies. In addition, regular exercise can delay the metabolic abnormalities in the human body and thus its aging. Physical training in a relatively short period of time (weeks or months) may increase the expression of many genes involved in improving exercise capacity [Booth, Laye, 2010]. It is also known that physical activity increases the positive mood and cognitive functions. However, the physiological background of these effects is not fully explained [Żołądź, Pilc, 2010].

Very spectacular discoveries concerning the body's adaptation to physical training were presented by Jan Holloszy. Well, he has proven that regular exercise may induce mitochondrial biogenesis in skeletal muscle and thereby improve exercise capacity [Żołądź, Pilc, 2010]. For many years, physical training was only associated with athletes and their preparation for competition championships. At present, association with the word "training" looks much different. It is due to increase the amount of research on the impact of physical activity (exercise) on the health of healthy untrained (no professionally-training, regular sports) and patients [Pedersen, Saltine, 2006].

According to Żołądź's and Pilc's statement (2010), previous studies have mainly focused on the effects of exercise on the systems: cardio - vascular and muscular. With time there is a new vision of the role of physical activity in the nervous system and many studies have begun. Demonstrated that moderate physical exercise play a great role in the prevention and improvement of many metabolic disorders in the human body [Żołądź, Pilc, 2010].

THE MEANING OF PHYSICAL TRAINING FOR CENTRAL NERVOUS SYSTEM

It is well known that the most diverse areas of older professionals are able to maintain high cognitive performance for more than 70 years of age. In some cases, older person equals or greater extent than young in different cognitive abilities mending training. It was also noted that the train a certain mental abilities had no impact to other mental abilities. The positive effects of exercise were only limited to tasks in training, ie, there was a lack of so-called "skills transfer" [Colcombe, Kramer, 2003].

Studies of the relationship between physical fitness and efficiency of the brain are carried about for decades. Experiments conducted in animals have shown that aerobic exercise increases: the blood supply to the brain, the number of synaptic connections and support the development of new neurons. As a result, the brain becomes more efficient, versatile and plastic, which explains the better results in aging animals [Colcombe, Kramer, 2004].

THE CARDIO – VASCULAR EFFICIENCY, CORTICAL PLASTICITY AND BRAIN AGING

The cardio - vascular efficiency is considered to be compensation for the performance of cognitive decline, but little else is known about the mechanisms of cortical causing these changes in humans.

Data from the studies: animal and human behavioural models or models with human neuroanatomical models point to the positive impact of the cardio - vascular efficiency for brain function in the elderly.

Revealed that aerobic exercise conducted in animals could increase the level of cerebral neurotrophic factor (BDNF) [Neeper et al., 1995] and other important neurochemicals, increasing the viability of neurons [Barde, 1994], the development and synaptic plasticity [Lu Chow, 1999]. Colcombe, Erickson et al. (2003) suggest that the benefit seen in animals may also occur in the brains of elderly people. This statement is based on the latest discoveries in human neuroanatomy. Once a researcher in his publication describes that observed among people aged 55-79 years reduce the trajectory of negative changes (age-related) in brain tissue as a function of the cardio – vascular efficiency. These effects were most evident in the cortex: frontal, prefrontal and parietal. These areas show the greatest changes due to aging, and are considered to be supportive executive cognitive function [Colcombe et al., 2004]. By using CFT (cardiovascular fitness exercise) in aging people, there is a considerable improvement of cognitive function Kramer et al. (1999), and Colcombe et al. (2002).

PRACTICAL EXPERIMENTS AND THEIR RESULTS –DESCRIPTION BASED ON SELECTED PUBLICATIONS

Spiriduso and Clifford in 1978, conducted a study in which compared several groups of people in advanced age: tennis players, runners, people leading a sedentary life. Their experiment was to carry out simple tests of choice and motor tasks. Older athletes have achieved it significantly better results than older people with sedentary lifestyle. Smaller benefits of practicing the exercises have been reported in young adults. Similar results (better results in the elderly) were also received other authors: Dutsman et al. (1994), Etnier et al. (1997).

By Colcombe, Kramer (2003), the above-mentioned studies were not sufficiently precise and therefore, suggested that the positive effects of exercise on the processes of motor, cognitive and perception may result from the predisposition of the persons concerned to provide rapid and specific answers, rather than a direct effect of efficiency aerobic exercise resulting from [Colcombe, Kramer, 2003]. Some researchers have resolved this trouble by using extended Embedded stimuli, but the information derived from them were not clear [Dutsman et al., 1994]. Dutsman et al. (1984), Hawkins, Kramer and Capaldi (1992), Riki and Edwards (1991) thus have carried out the research, noted that aerobically trained individuals fared better than untrained [Colcombe, Cramer, 2003].

META –ANALYSIS – COLCOMBE AND KRAMER

The studies on people have not given so obvious results, such as those involving animals. According to Colcombe and Kramer (2003), part of the confusion in the study of human beings may result from methodological factors. eg. tests were conducted on different age groups. The study also differed in terms of the type, intensity and length of aerobic activity, type of the exercise, general health and physical condition of participants, gender of respondents, tasks aimed to investigate various cognitive functions, as well as the composition of the groups studied. In addition, research on the impact of physical activity on cognitive processes differed the theoretical ground and it influenced the selection of fitness tasks.

Some researchers in the selection of motor tasks were not guiding by any of the theoretical justifications, while others [Dutsman et al. 1984 Spiriduso and Clifford 1978] assumed that the results could be observed when performing simple tasks (reaction time), eg.: tapping fingers. Such tasks allow the capture reaction of the central nervous system without interference from a higher level of cognitive or without a deliberate action of the test. Colcombe, Kramer (2003) described the purposes of its analysis as hypothesis SPEED.

Shay and Roth (1992), and the Stones and Kozma (1989) assumed that the effects of exercise is best could be seen in the performance of visual – spatial tasks. Theoretical basis for the selection of such a task was that visual - spatial processes are more susceptible to aging than verbal skills. Colcombe and Kramer have called this „visual – spatial hypothesis".

Chodzko - Zajko et al. (1991, 1994) concluded that the best for these purposes are suitable tasks that require careful consideration, precise execution. Researchers refer to this hypothesis, "careful processing." Theoretical back to this hypothesis were earlier study by Schneider and Shiffrin (1997), which helped to formulate the theory of skill acquisition, according to which the components of the tasks or skills transferred from carefully processed to automatic as a result of continuous exercises.

The fourth hypothesis created was a meta - analysis of Colcombe, Cramer [Kramer, Hahn et al., 1999; Hall, Smith, Keele, 2001]. The authors concluded that the improvement in efficiency would find reflected in the improvement of executive- control processes, eg.: coordination, inhibition, planning, active memory. Such tasks differ from those of controlled, since the time of their execution is not automatic. In addition, they require constant mediation central nervous system. According to the West (1996) executive processes - and control areas of the brain responsible for it, have a significant susceptibility to aging.

The researchers point out that these four above hypotheses are only an approximation of the theoretical discussion of the impact on the efficiency of cognitive processes in humans, but it is a key starting point for understanding the published studies, not always containing clear and meaningful conclusions. In other words, even those underdeveloped, incomplete hypothesis may enable the creation of a structure and allow to deeper understanding of data collected from studies on the effects to improve aerobic fitness on the human brain and improvement the cognitive functions.

Colcombe, Kramer put the question asked: why some studies have shown an increase in efficiency due to the increased aerobic fitness, while in other, the similar relationship was not observed? For this purpose, they used the technique of meta- analysis in the extension studies the effects of exercise on cognitive processes of older people.

Colcombe and Kramer (2003) conducted a meta-analysis of four of the above hypotheses and several methodological factors that may affect the extent to which an increase in aerobic fitness improves cognitive performance. The authors have chosen this method because they believed it will be great for their study. It allows for a summary of the relationship between two variables in the cross section of various studies, and in this case specifically, the impact of fitness on cognitive function. It also serves to determine whether one or more variables affected the results.

EXPERIMENTS WITH USING CFT

Colcombe, Kramer et al. (2004) described in their publication the two separate experiments showing (according to our knowledge) the first time in humans, that increase of the cardio - vascular efficiency resulting in enhancement of key aspects of brain activity during tasks with the use of cognitive processes. In this study, dexterous people (A) or exercised aerobically (B) exhibited greater activity of the prefrontal and parietal areas of the cerebral cortex during a job than those who were inefficient or untrained aerobically.

Study participants had to find the correct answer by displacing or filtered out misleading information (as circumstantial). The authors observed using MRI brain centres that were activated when generating responses in terms of non-compliance, while confusing stimuli must remain neglected. By imaging the brain when performing such tasks, identified several areas involved in selective attention and resolve problems arising from obtaining conflicting stimuli. The authors argue, as Barcelo et al. (2000) and van Veen et al. (2001), that the successful execution of these tasks using incompatible stimuli requires the elderly to use selective attention through the front and parietal areas of the brain, which in turn affects the visual areas of the cerebral cortex, forcing it to extract the central (target) stimulus and rejection peripheral stimuli. During the normal process, while these areas are stimulated, the information provided by peripheral stimuli are reduced and this leads to a reduction in the stage of response conflict and bringing to the correct answer. This reduction of the conflict in the stage of response could be observed behaviourally (shortening the reaction time to respond) and neuroanatomical (brain imaging by magnetic resonance imaging - MRI). Due to the cortex anterior cingulate (ACC) is sensitive to conflict reaction and recognized as signalling the need to adapt the control process is the successful execution of this task, it should also results increasing the activity in ACC.

As a result of experiments, the authors found that participants who began the study with a high degree of efficiency (A) or participants who, by increasing the cardio – vascular efficiency (B) show a reduced activity in the ACC (area related to the presence of the conflict and the need to adapt to behavioural attention- control processes).

Also found that the benefits of cardio - vascular fitness could be seen in the short term (6 months).

Authors, on the basis of their experiments and literature, assume that the increase in the of cardio – vascular efficiency causes an increase in the number of synapses in the frontal and parietal cortex, allowing greater use of these areas with difficult and intensive cognitive task. May also be that an increase in the efficiency leads to the brain angiogenesis, and thus better blood circulation in the brain. Blood and metabolic provide more resources (fuel) consumed during the brain functioning.

BDNF AND PHYSICAL TRAINING

BDNF is moving anterogradly, which means: from cells body of the tabs associated with the ends of synaptic vesicles from which it is secreted. TrkB receptor for BDNF present in presynaptic membrane and postsynaptic parts: dendrites of neurons in the brain, muscle fibers at the neuromuscular – muscle junctions. Neurotrophins are able to move in both directions: adaxially, abaxially and subcellular localization of the receptors could be concluded that the neurotrophins act as neuromodulators.

In recent years, numerous studies have shown that physical exercise increases the expression of BDNF in the rat brain. There are many attempts to examine the BDNF in humans - eg. some have shown that physical activity could increase the concentration of BDNF in humans in plasma. Żołądź and Pilc (2010), based on the analysis of the scientific literature, have concluded that there may be potential benefits (improved functioning of the body) flowing to induce increased expression of BDNF and its release in the brain and peripheral tissues.

Murphy, Miller and Chaplain's studies have demonstrated that BDNF is dependent on the neuronal activity. It has been proved that, under the influence of immediate stimulation of the neuron occurs the activation of BDNF expression - is an indication to the conclusion that BDNF is a regulatory protein that is involved in the rapid changes in synaptic. In contrast, increased expression of TrkB and its ligand in cells stimulated electrically or by BDNF causing an ejection of BDNF into the slot of the synapse and subsequent activating TrkB receptors is a self-reinforcing loop neuron activation. This loop "*may explain the formation of synaptic long-term potentiation (LTP), which is the gateway to fix plastic changes*" [Skup, Nowak, Zawilska 2004]. In the interaction of pre- and postsynaptic elements, fits the facilitation scheme involving a cascade: BDNF - TrkB- MAPK - synapse. BDNF activates presynaptic locally in part by MAP kinase receptor TrkB. MAP kinases act on synapsin (protein responsible for passage of the synaptic vesicle that interact with the actin cytoskeleton by changing its phosphorylation). Here there is also the activation process of membrane structures which are surrounded by the clathrin, which is associated with increased internalisation (under the action of neurotrophins) proteins and membrane receptors. Accordingly, TrkB receptors also regulate the release of neurotransmitters and thus neurotransmission by inducing changes in the active zone of the nerve ending.

It is worth noting that the development of the morphology of the nerve cells under the influence of BDNF could occur in many ways. This is related to the presence of different receptor TrkB, which mediates signal transduction. Truncated forms of TrkB stimulate dendritic branching tabs at the base of the dendritic tree, and full forms causing elongation of the end (distal) dendrites, which grow at the top of the tab. Both types of receptors may be present on a single neuron, which allows the modelling (Skup, Smith, Zawilska 2004).

Zhang and his research team [Zhang et al., 2007] demonstrated strong expression of BDNF in different parts of the brain, eg monkeys. In the cortex (III and IV layer), hippocampus, granulosa cells, the midbrain, in the pons, medulla, thalamus and nuclei of the hypothalamus and other brain areas. Similarly, human BDNF expression has been demonstrated among others in the hippocampus, amygdala [Murer, Boissiere, Yan, 1999]. BDNF is involved in the development of synaptic plasticity and acts by TrkB receptor [Kožíšek, Middlemas, Bylund, 2008], regulates a number of processes including neuronal development and its functions. It is involved in the formation of memory, including learning and behaviour, synaptic plasticity and synaptic connections and neurons. Promotes the development of immature neurons and increases the survival of adult neurons [Binder, Scharfman, 2004].

By Monteggia et al., BDNF's role in the adult brain may be different than in the developing brain. Loss of BDNF in the brain of adult mice caused damage to the hippocampus. In contrast, BDNF loss during early development led to hyperactivity disorder, as well as more serious disorders in learning (in hippocampus-dependent learning) [Monteggia, Barrot, Powell, 2004].

BDNF, like the other neurotrophins, is synthesized from a precursor (pro-BDNF), which is then cut and converted to mature. This neurotrophin works through two types of receptor TrkB and p75 NTR. Pro-BDNF beneficial effect on p75 NTR, but mBDNF selectively binds and activates TrkB. In this way, different isoforms of BDNF generate sometimes opposing effects.

Moreover, registered that p75 NTR activation by endogenous pro-BDNF during the depression (LTD), in the hippocampus, induced apoptosis in peripheral neurons. In contrast, activation of TrkB by mBDNF is crucial for long-lasting LTP and regulates neuronal development and their functioning [Żołądź, Pilc, 2010].

Yang et al. (2009) have demonstrated that stimulation of the muscles contributes to the secretion of pro-BDNF, which causes synaptic strengthening or depression - it depends on whether BDNF is proteolytically cleaved or not. In order to evaluate the effect of BDNF released on the organism's physiology, it is important to determine the amount / proportion of proBDNF and mature BDNF released from the neurons [Żołądź, Pilc, 2010].

Nepher et al. (1995) were the first who noticed the positive correlation between the average distance in the circle after which the animals were running and BDNF mRNA in the hippocampus and cerebral cortex of rats tested. Moreover Nepher and his team have shown that 2-7 days exercise resulted in a significant increase in BDNF mRNA in the rat hippocampus [Nepher et al., 1996]. Oliffe et al. also demonstrated that the expression of mRNA in the rat brain correlates with the distance during the voluntary taken activity. It has showed that six hours of training is sufficient to regulate mRNA expression BDNFu. This expression is maintained at an elevated for 12 hours after physical activity. Rasmussen et al. noted that a single unit training resulted in increased regulation of BDNF in the hippocampus and cerebral cortex of mice with a peak two hours after the end of exercise on a treadmill. According to Bert Berchtold, to a significant increase in BDNF regular workouts lead. He noted that after 14 days of training, there was a significant increase in the BDNF expression. This level has been rising until the end of the training period (up to 90 days). Such increased amount of BDNF remained about 7 days after training.

The influence of the same type of exercise performed on alternating days without exercise was examined as well. It has been found that this type of training could also increase the BDNF in the rat hippocampus. However, this increase was much slower, and the effects disappeared quickly after training. Also systematic physical training may increase the level of BDNF in the brain but the most effective is the daily training for a few months [Żołądź, Pilc, 2010].

Liu et al. (2009) conducted observations on the effects of various physical activities. They compared the effects of running on a treadmill and voluntary activity in the wheel running. Have shown that these two different training have different effects in different areas of the brain and affect its function - the effect of different forms of exercise difference the plasticity and cause varying effects on different forms of learning and memory. According to the Żołądź's and Pilc's (2010), this effect should be taken into consideration during the interpreting of the impact of exercise on brain plasticity and its functioning.

SUMMARY

Through physical activity, especially aerobic, a man in a simple and cheap way could prevent the aging process of the body and nervous system. Confirmation of this finding is that the research conducted in animals and humans show the positive role of physical activity: increasing the blood supply of the brain (under the influence of physical training), increased synaptogenesis and neurogenesis (under the influence of learning motor skills), inhibition of aging. This all means that the brain is more malleable and works efficiently [Colcombe, Kramer, 2004].

By using the fitness cardio - vascular exercises (CFT) in aging humans, could be clearly improve their cognitive function and thereby reduce the likelihood of dementia. A significant improvement was observed under the influence of aerobic training, but turned out to be the most effective aerobic training combined with an effort forcefulness. In order to obtain the best possible effect, exercises should take about 30 minutes or more [Kramer et al., 2004, 2006; Colcombe et al., 2002]. The increase in cardiac efficiency - vascular increases the number of synapses in the frontal cortex and parietal (Kramer et al., 2006).

Exercises by stimulating the development of new blood vessels in the hippocampus, cerebellum and motor cortex are assumed as a method to reduce the damage caused by stroke [Kramer and Erickson, 2007].

As a result of the meta-analysis, the authors found that aerobic training has a significant impact on cognitive function of the elderly sedentaryes

It was concluded the greatest benefits of performing the executive - control tasks. The tasks of a controlled, overlapping the executive and visual – spatial processes, also showed noticeable positive effects of physical activity. The results of the meta - analysis and other tests are a source of further hypotheses to verify [Colcombe, Cramer, 2003].

There are many studies showing that older people active in sports are more efficient than older not physically active people [eg. Spiriduso and Clifford, 1978].

Under the influence of long-term physical training, changes in the functioning and brain activity occur (the study of meta - analysis, Colcombe, Cramer, 2004).

There is a relationship between secretion of BDNF and the physical effort performed during running [Nepher et al., 1995]. BDNF complies the critical role in neuroprotection and neurogenesis.

Unusual training could result in increase of BDNF expression within brain. However, more effective is the daily, systematic training [Żołądź, Pilc, 2010].

It is worth to emphasize, that study groups with a predominance of women showed greater effects of exercise influence on cognitive function, suggesting a positive role not only exercise, but may oestrogens [Kramer, Erickson, 2007; Colcombe, Kramer, 2003].

REFERENCES

1. Barde Y. (1994), *Neurotrophins: a family of proteins supporting the survival of neurons*. Prog Clin Biol Res. 390:45-56.
2. Barcelo F., Suwanzono S. et al. (2000), *Prefrontal modulation of visual processing in humans.* Natur Neuroscience 3(4): 399-403.
3. Binder., Scharfman. (2004), *Brain-derived neurotrophic factor*. Growth Factors.Sep;22(3): 123-31.

4. Bloss E., Janssen W., Mc Ewen B., Morrison J. (2010), I*nteractive effects of stress and aging on structural plasticity in the prefrontal cortex.* J. Neurosci 30, 6726-6731.
5. Bloss E., Janssen W., Ohm D. (2011), *Evidence for reduced experience-dependent dendritic spine plasticity in the aging prefrontal cortex*. J Neurosci 31, 7831-7839.
6. Booth F., Laye M. (2010), T*he future: genes, physical activity and health*. Acta Physiol, (Oxf), 199: 549 – 556
7. Burke S., Barnes C. (2006), *Neural plasticity in the aging brain*. Nat Rev Neurosci 7, 30-40.
8. Chodzko – Zajko W. (1991), *Physical fitness, cognitive performance, and aging*. Med Sci Sports Exerc. 23(7):868-72.
9. Chodzko – Zajko W., Moore K. (1994), *Physical fitness and cognitive functioning in aging.* Exerc Sport Sci Rev. 22:195-220.
10. Colcombe S., Kramer A. (2003), *Fitness effects on the cognitive function of older adults: a meta – analytic study.* Psychol Sci, 14: 125 – 130.
11. Colcombe S., Kramer A., et al. (2004), *Cariovascular fitness, cortical plasticity, and aging.* Proc Natl Acad Sci, USA, 101(9): 3316 – 3321.
12. Dumitriu D., Hao J, Hara Y. (2010), *Selective changes in thin spine density and morphology in monkey prefrontal cortex correlate with aging-related cognitive impairment.* J Neurosci 30, 7507-7515.
13. Dutsman R., Ruhling R., Russell E., Shearer D., Bonekat W., Shigeoka J., Bradford D. (1984), *Aerobic exercise training and improved neuropsychological function of older adults.* Neurobiology of Aging, 5, 35- 42.
14. Dutsman R., Emmerson R. & Shearer D. (1994), *Physical activity, age, and cognitive neuropsychological function*. Journal of Aging andPhysical Activity, 2, 143 – 181.
15. Etnier J., Salzar W., Landers D., et al. (1997), *The influence of physical fitness and exercise upon cognitive functioning: A meta – analysis.* Journal of Sport and Exercise Psychology, 19, 249 – 277.
16. Fordyce D., Farrer R. (1991), *Effect of physical activity on hippocampal high affinity choline uptake and muscarinic binding: a comparison between young and old F344 rats.* Behav. Brain Res, 46, 123-133.
17. Górska T., Grabowska A., Zagrodzka J. (2005), *Mózg a zachowanie,* 544-551.
18. Kołodziejczyk I. (2007), *Neuropsychologia starzenia poznawczego*. Kosmos, 56, 1-2 (274-275).
19. Kozisek M., Middlemas D., Bylund D. (2008), *Brain – derived neurothropic factor and its receptor tropomyosin – related kinase B in the mechanism of action of antidepressant therapies,* Pharmacol Ther, 117: 30 – 51.
20. Kramer A., Bherer L., Colcombre S.(2004), *Enviromental influences on cognitive and brain plasticity during aging*. J. Gerontol., A: Biol. Sci. Med. Sci. 59, M940-M957.
21. Kramer A., Erickson K., Colcombre S. 2006*), Exercise, cognition, and the aging brain.* J. Appl. Physiol. 101, 1237-1242.
22. Kramer A., Hahn S., Cohen N. (1999), *Ageing, fitness and neurocognitive function*. Nature. 29;400(6743):418-9.
23. Liu Y., Chen H., Wu L., et al. (2009), *Differential effects of treadmill running and wheel running on spatial or aversive learning and memory: roles of amygdalar brain – derived neurothropic factor and synaptotagmin I. J Physiol,* 3221 – 3231.
24. Marchewka A., Jungiewicz M. (2008), *Aktywność fizyczna w młodości a jakość życia w starszym wieku.* Gerontologia Polska 16, 127-130.
25. Monteggia L., Barrot M., Powell C., et al. 2004), *Essential role of brain – derived neurothropic factor in adult hippocampal function*. Proc Natl Acad Sci, USA, 101: 10827 – 10832.

26. Murer M., Boissiere F., Yan Q., et al. (1999), *An immunohistochemical study of the distribution of brain-derived neurotrophic factor in the adult human brain, with particular reference to Alzheimer's disease*. Neuroscience, 88(4):1015-32.
27. Neeper S., Gomez P. (1995), *Exercise and brain neurotrophins.* Nature, 373, 109.
28. Oliff H., Berchtold N. (1998), *Exercise-induced regulation of brain-derived neurotrophic factor (BDNF) transcripts in the rat hippocampus*. Brain Res Mol Brain Res. 30;61(1-2):147-53.
29. Pedersen B., Saltin B. (2006), *Evidence for prescribing exercise as therapy in chronic disease.* Scand J Med Sci Sports, 16(Suppl): 3 – 63.
30. Peters A., Sethares C., Luebke J. (2008), *Neural plasticity in the aging brain*. Nat Rev Neuroscience 7, 30-40.
31. Petralia R., Mattson M., Yao P. (2014), *Communication breakdown: The impact of ageing on synapse structure.* Aging Res Rev, in print.
32. Piechota M., Sunderland P. (2014), *Starzenie neuronów*. Postępy Biochemii 60 (2), 177-186.
33. Rasmussen P., Brassard P., Adser H. (2009), *Evidence for a release of brain-derived neurotrophic factor from the brain during exercise*. Exp Physiol. Oct;94(10):1062-9.
34. Shay K., Roth D. (1992), *Association between aerobic fitness and visuospatial performance in healthy older adults*. Psychol Aging, 7 (1): 15-24.
35. Van Praag H., Christie B., Sejnowski T., Gage F. (1999), *Running enhances neurogenesis, leraning, and long – term potentiation in mice.* Proc Natl Acad Sci USA. 96: 13427 – 13431.
36. West R. 1996). *An application of prefrontal cortex function theory to cognitive aging.* Psychological Bulletin, 120, 272-292.
37. Yang J., Siao C., Nagappen G., et al. (2009), *Neuronal release of proBDNF.* Nat. Neuroscience 12: 113-115.
38. Zhang H., Li L., Zou X., et al. (2007), *Immunochistochemical distribution of NGF, BDNF, NT – 3, and NT – 4 in adult rhesus monkey brains*. J Histochem Cytochem, 55: 1 – 19.
39. Żołądź J., Pilc A. (2010), *The effect of Physical activity on the brain derived neurothropic factor: from animal to human studies.* Journal of physiology and farmacol, 5: 533 – 541.