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REGULAR AEROBIC EXERCISE ENHANCES MEMORY AND COGNITION- A REVIEW

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ABSTRACT

Aerobic exercise is the type of exercise done through walking, jogging, cycling, stair climbing, rowing or swimming. It increases the stroke volume, improves cardiovascular efficiency. It increases the respiratory rate and efficiency of breathing muscles of respiration. It also increases the musculoskeletal efficacy and strengthens muscles, tendons, ligaments and bones. Regular physical exercise improves the thinking capacity and memory skills of individuals. They denoted that pumping of heart during exercise and excess sweating increases the boosting of the hippocampal size and improves verbal learning and memory. Another study evaluated the preferred mode of exercise to improve brain 's cognition was physical training by aerobic compared to strengthening exercises. Aerobic exercise may be preferable over balance training done through coordination, balance and flexibility exercises. Neurotransmitters like serotonin and acetylcholine levels are raised in exercising brains of rats and the medial septal GABAergic neurons play a key role in influencing the exercise induced cognitive processes. This exercise strategy offers significant neuroprotection, neuron survival and synaptic plasticity.

INTRODUCTION

Aerobic exercise is the ability of a person to do physical fitness involving cardiovascular and muscular systems to provide necessary oxygen and energy requirements to all larger muscular groups over a period of time. Aerobic exercise can be done through walking, jogging, cycling, stair climbing, rowing or swimming for 30 mins and the optimal duration is 3-7 days per week.

BENEFITS OF AEROBIC EXERCISE

Aerobic exercise increases the blood volume and cardiac output to muscles. It increases the stroke volume, improves cardiovascular efficiency. It increases the respiratory rate and efficiency of breathing muscles of respiration. It also increases the musculoskeletal efficacy and strengthens muscles, tendons, ligaments and bones. It also depletes the fat resources of the body. This type of exercise decreases the risk of developing diabetes mellitus, coronary artery diseases and cancer (*Website*, no date a)

Many reasons have been proposed on the concept that Regular physical exercise improves the thinking capacity and memory skills of individuals. They denoted that pumping of heart during exercise and excess sweating increases the boosting of the hippocampal size and improves verbal learning and memory. But resistance training, balancing exercises and exercises that tone the muscles does not cause any structural and functional changes in the hippocampus (*Website*, no date b)

Many studies have worked on this association linking regular exercise and cognitive training. 140 inactive older individuals were assigned to aerobic exercise, computerized cognitive training and a combination of these two trainings and a control group. This assignment was performed for a period of 3 months, that is 5 days per week, each session for 45 mins. Parameters evaluated were physical fitness and cardio respiratory using Rockport 1 mile walk test and Maximal aerobic capacity (VO₂ max) was estimated ; cognitive tests by Montreal Cognitive Assessment and Mini-Mental State Examination; psychological tests using a Questionnaires to assess sleep quality, depressive symptoms and emotional status, functional and structural brain scans using Magnetic Resonance Imaging and blood sample collection for doing Hemogram, biochemical parameters, and lipidic profile. All these parameters were evaluated before and after the intervention. These parameters are related to brain neuroplasticity. Results revealed that Aerobic exercise regimen improved executive functions and speedy memory and Cognitive training improved higher intellectual functions like information processing speed, memory and executive functions. The combination therapy regimen showed greater cognitive functions and memory. [Alba Castells-Sánchez](#), 2019)

Another review study evaluated the hypothesis that physical exercise (PE) is an efficient genetic modulator to increase the benefits on cognitive function and alter structural and functional changes in brain. This review focused on positive effects on biological and psychological effects in animal as well as human studies. Animal studies that worked on motor exercise greatly improvement in spatial abilities (*Website*, no date c; van Praag, 2005) and increased the cognitive domains like executive functions (Langdon and Corbett, 2012). These studies concluded that motor exercise greatly improved cognitive functions in animals.

Few other studies promoted that motor activity that was performed before the development of neurodegeneration offered a protective role against the formation of beta amyloid plaques in Alzheimer's disease (Adlard, 2005; Richter *et al.*, 2008; Langdon and Corbett, 2012)

Human studies performed evidenced Neuroplasticity after Physical Exercise as denoted by structural changes in frontal and hippocampal regions with increased volume of grey matter and reduced damage to grey matter of brain. (Colcombe *et al.*, 2006) (Colcombe *et al.*, 2006; Chaddock-Heyman *et al.*, 2014). Another concept is that Physical exercise training increases the cerebral blood flow and improves cerebrovascular health following release of neurotrophic factors like BDNF (Brain derived neurotrophic factor) (Mandolesiet *et al.*, 2017). (Hötting *et al.*, 2016)

A research evaluated the enhancing capacity of aerobic exercise on cognition among older and younger individuals. The study investigated 270 sedentary but healthy cognitively good in the age group between 20-68 years and were assessed for resting cerebral blood flow scans and functional magnetic resonance imaging fMRI after 6 months of training. The important correlates of the study were of structural, metabolic, and cognitive activation through fMRI studies and apolipoprotein E and other inflammatory markers. Significant improvements have been observed in fMRI with an increase in density of grey matter of brain and improvement in task related activation. (Stern *et al.*, 2019)

A research evaluated the efficacy of aerobic exercise on cognitive parameters and biomarkers that associate with the pathology of Alzheimer disease in older individuals in the age group between 55 to 85 years. These individuals were subjected to high intensity aerobic exercise for 45 to 60 min/d for 4 d/wk in a period of 6 months. Biochemical tests for glucose metabolism and treadmill test for physical and cardiovascular reactions and distribution for fat was assessed by dual-energy x-ray absorptiometry. Cognitive tests were measured by verbal fluency, Stroop, task switching, Story recall and list learning. Fasting levels of Cortisol, Insulin, BDNF and Insulin like growth factor. Results revealed that six months of aerobic exercise vs stretching increased the cardiovascular fitness as shown in increase in $\dot{V}_{O_2}$ peak in treadmill exercise; Improved cognitive abilities like multi-tasking, processing of information, higher intellectual functions, cognitive flexibility etc.; It also increased the sensitivity to insulin and decreased the circulating levels of cortisol and BDNF ('Improving Cognition via Exercise (ICE): Study Protocol for a Multi-Site, Parallel-Group, Single-Blind, Randomized Clinical Trial Examining the Efficacy of Aerobic Exercise to Improve Neurocognition, Daily Functioning, and Biomarkers of Cognitive Change in Individuals with Schizophrenia', 2019)

Another study also confounded similar results. The benefits of aerobic and other physical exercises increase the control of executive processes of thinking skills like planning, organization, execution, multitasking and working memory and selective attention in older people especially compared to younger individuals. (Colcombe *et al.*, 2006)

Some prospective imaging studies of the brain suggest Aerobic fitness in healthy older individuals with good cognitive health is greatly associated with increased blood perfusion to regions of the brain involved in cognitive processing and reduced atrophy of the brain. A prospective brain imaging study suggests that increased aerobic fitness in cognitively healthy older adults is associated with reduced age-related atrophy and increased perfusion in

regions that support executive control and memory consolidation but this change is more vulnerable to the process of aging too. Aerobic exercise practice for a period of Six months increased the executive control processes in women with Middle cerebral Infarction (MCI). And plays a protective role in the attenuation and progression of cognitive symptoms in MCI. It has been reported to reduce the risk of developing cognitive loss after severe and moderate exercise among women. (Daniels, 2006)

Cognitive function is one of the most important functions of the brain for an aging brain, Although, many complications advance with aging, hypertension too accelerates the process of brain aging and cause cognitive loss. (Wilson *et al.*, 2013)

A research study investigated the effects of acute aerobic exercise on cognitive ability among middle aged hypertensive adults. The participants underwent tests for cognition like memory processing, - back and flanker tasks in pre and post cycling with approximately 55% of peak O₂ consumption. Their results believed that exercise exhibited similar changes in cognitive functions like increased memory recognition and decision making abilities in normal as well as hypertensive groups. (Steinberg *et al.*, 2015)

Another study evaluated the preferred mode of exercise to improve brain 's cognition whether physical training by aerobic and strengthening exercises may be preferable over balance training done through co-ordination, balance and flexibility exercises. Aerobic exercise not only involves some neurocognitive demands but also improves physical and cardiovascular fitness. (Paffenbarger, Blair and Lee, 2001). Participants who performed balancing exercises through repeated static and dynamic exercises on unstable and stable surfaces for balancing significantly decreased EEG frequencies over prefrontal cortex. frequencies over the prefrontal cortex.

On Comparing the performance in cognitive executive functions, working memory, go/no-go, divided attention, and set-shifting tasks, the balancing exercise strategic group improved only in set shifting task alone, but the aerobic training groups showed improvements in all the tasks, the balance exercising group showed improvement in set-shifting task alone. The exergame group showed a significant improvement in all tasks. (Paffenbarger, Blair and Lee, 2001; Netz, 2019)

Some studies evaluated the detrimental effects of prolonged sitting leading to cognitive impairment. (Carter *et al.*, 2018; (García-Hermoso *et al.*, 2018)). Researchers suggested that more time spent on sedentary quests significantly reduces executive function in hypertensive individuals compared to normal people. (Steinberg *et al.*, 2015). And if these time spent on sedentary quests are replaced by physical quests are replaced by physical exercise, it obviously prevents the such decline in cognitive performance (Baker *et al.*, 2018)

Some cross sectional studies found that significant decline in brain tissue densities caused by aging in frontal, parietal, and temporal cortices were decreased substantially cardiovascular fitness. (Colcombe and Kramer, 2003)

POTENTIAL MECHANISMS LINKING THIS ASSOCIATION

The Potential mechanisms that explain the cognitive abilities of aerobic exercise are improved vascularization, increased survivability of neurons functionally, decreased inflammation of neurons, and neuroendocrine response to stress and reduced formation of amyloid plaques. (Fordyce and Farrar, 1991)

Studies on patients with early stages of Alzheimers disease (AD), the levels of cortisol was relatively high and these levels suggest increased disease progression. The Hypothalamic-pituitary-adrenal axis work heavily in AD and compromise the response of the brain to stress and this increases the vulnerability for neurodegenerative diseases. (Peskind *et al.*, 1996)

Other additional contributions explaining this association of post exercise facilitation of cognitive improvement may be due to increased release of brain-derived neurotrophic factor and catecholamine or endorphin-mediated increase in arousal responses. (McMorris *et al.*, 2008; Dishman and O'Connor, 2009). Though possible explanations associated between aerobic exercise training with cognitive improvements, larger studies using novel methods are potentially required to further investigate this aspect.

Anderson-Hanley with his colleagues suggested two explanations for improvements caused by the combination of physical and cognitive task and cognitive task alone. The compounding effects directly add the mental exercise to cognitive training to target the overall ability and another explanation is that cognitive training acts synergistically with physical exercise training to improve the higher intellectual thinking and executive functions and cognition. (Anderson-Hanley *et al.*, 2012)

Patients with heart failure are at a greater risk of cognitive impairment due to the reason that inadequate blood flow followed by inadequate perfusion decreases the oxygen delivery to brain tissues. Because of it, there is a substantial neuronal loss resulting in dementia and so restorative therapies and interventions that can reverse and prevent the cognitive loss are much important. Aerobic exercise is reported to improve cerebral perfusion and oxygen delivery to tissues and promotes neurogenesis and neuroplasticity, thereby improving cognitive execution like attention, memory, recall of information, psychomotor speed and cognitive execution. Thus, researchers promoted that aerobic exercise is an adjunct therapy for decline of cognitive function in patients with heart failure. (Website, no date; Anderson-Hanley *et al.*, 2012). Many structural and functional changes of cerebrum in grey and white matter and neuroplasticity was observed through brain imaging.

Neuroplasticity is the process by which the nervous system adapts to changes of environment to optimize its function. The process of brain aging is characterized by loss of white and grey matter in parietal, temporal and prefrontal areas of the brain. Such structural changes can be and cognitive loss can be enhanced by aerobic exercise (Hötting and Röder, 2013; Jensen, Andersen and Akay, 2014)

Animal models- Signaling pathways

A number of factors link the release of BDNF to cognitive function after aerobic exercise. This exercise strategy offers significant neuroprotection, neuron survival and synaptic plasticity. Animal models suggested that exercise increased mRNA and protein BDNF in brain regions like hippocampus, frontal cortex and cerebellum. These findings provide a strong evidence that aerobic exercise raises the BDNF levels and improve the cognitive behavior. Another aspect is that Insulin-like growth factor-1 is an important factor that induces angiogenesis and neurogenesis. If IGF-1 is blocked, there is a highly significant decrease in the formation of new capillaries and blocks the influx of VEGF into the brain. Thus, it eliminates exercise-induced neurogenesis. Neurotransmitters like serotonin and acetylcholine levels are raised in exercising brains of rats and the medial septal GABAergic neurons play a key role in influencing the exercise induced cognitive processes.

Aerobic exercise training improves attention, execution and cognitive functions even in younger and middle aged persons of participants of Columbo University of Physicians and Surgeons. This exercise training is associated with structural changes shown by increased cortical thickness of the caudal middle frontal cortex of left hemisphere and this increase in grey matter did not associate with age of the participants. (Website, no date e)

The Physical activity Guidelines evidenced that Americans who did moderate intensity exercise for two days of strengthening at least 150 mins or vigorous exercise for 70 mins, significantly prevented the occurrence of chronic diseases like dementia. (Website, no date f). The probable mechanisms explained in this association is that aerobic exercise increases the heart rate and blood flow that is pumped to the brain. This improves the neurogenesis raises the volume of the brain and improves the memory and cognitive functions. Neurogenesis led by aerobic training raises cognitive reserve and helps to buffer against harmful effects of dementia. (van Praag, 2008)

, the increased production of neurotrophins improves brain plasticity, learning and memory; it also aids the neuron survival and function. (Livingston, 2017). The neurotransmitters like serotonin and nor epinephrine surge after aerobic training, so that it improves information processing, mood and behavior. (Meeusen and De Meirleir, 1995; van Praag, 2008)

A study was conducted to explore the benefits of aerobic training on three types of types of people. People lost weight with restrictive dieting; People who lost weight with exercise; People who used a combination of Restrictive dieting and exercise. The study found marked marked improvements in cognition in the combination group. (Napoli *et al.*, 2014)

Also, that the type of exercise involved in aerobic training is of considerable importance. A study worked on the protocol of multi component exercise regimen coding for flexibility, balancing and aerobic fitness. One such type of exercise is "TAI CHI" which found profound benefits on cognitive functions compared to other type of exercises. (Wayne *et al.*, 2014)

Exercise training triggers physiological responses like increase in insulin levels, promotion of inflammation and production and release of endorphins

and growth factors. These chemicals stimulate neuronal growth, improve sleep and mood, reduce anxiety, so that tasks that aim cognitive function and concentration can be performed optimally [Website](#). A study was conducted by researchers of University of British Columbia where they observed that aerobic exercise regimen improves circulation to hippocampus, boosts its size and thereby improves verbal learning and memory.

Regular physical exercising in older adults prevents influences of aging in the body and prevents cognitive loss. Especially in Alzheimer's disease, dementia and Schizophrenia, this type of exercise is considerably important to avoid memory loss and mood changes. ([Website](#) :)

Another recent study observed that cardiovascular ill health increases the risk of Alzheimer's disease and dementia. The reason being higher cholesterol levels and resultant hypertension results in cognitive loss and impairment. ([Website](#)). Thus, exercise strategies that focus on management of Hypertension and high cholesterol levels can help to avoid risk of Alzheimer's disease. (Website)

Another study conducted at Rush University Medical Centre observed that active old individuals with brain lesions and dementia can improve cognitive abilities after aerobic training. ([Buchman et al. 2019](#))

CONCLUSION

Aerobic exercise improves cardiovascular efficiency and respiratory fitness. Aerobic training also improves attention, execution and cognitive functions even in younger and middle aged persons. The potential mechanisms that explain the cognitive abilities of aerobic exercise are improved vascularization, increased survivability of neurons functionally, decreased inflammation of neurons. Thus, practice of regular physical exercising in older adults prevents influences of aging in the body and prevents cognitive loss, especially in Alzheimer's disease, dementia and Schizophrenia.

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