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Assessment of the effects of physical activity on cognitive functions: An integrative review

Avaliação dos efeitos das atividades físicas nas funções cognitivas: Uma revisão integrativa

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Abstract

Physical activity is considered effective in the control and prevention of several diseases. More recently, some authors have been suggesting that physical exercise is able to promote both synaptogenesis and neurogenesis. This ability could promote a natural cognitive improvement of the establishment of new neural networks in healthy people as well as in individuals with some neurodegenerative disease. The purpose of this study was to review the main studies in the literature on the effects of exercise on cognition from the measurement of several variables (e.g., attention, perception, memory). This work appears as a review of non-systematic literature. The data presented below indicate that the cognitive improvement depends on the type of exercise (aerobic or anaerobic), frequency and intensity of practice, age, and other factors discussed that could influence the cognitive performance of the participants.

Keywords: cognition, physical activity, executive functions

Resumo

A prática de atividades físicas é considerada eficaz no controle e prevenção de diversas doenças. Mais recentemente alguns autores vêm sugerindo que o exercício físico é capaz de promover tanto sinaptogênse quanto neurogênese. Esta capacidade poderia promover uma melhora cognitiva natural do estabelecimento de novas redes neurais tanto em pessoas sadias quanto aquelas possuam alguma doença neurodegenerativas. A proposta deste trabalho foi revisar os principais estudos na literatura sobre os efeitos do exercício físico na cognição a partir da mensuração de diversas variáveis (atenção, percepção, memória, etc). Este trabalho configura-se como uma revisão da literatura não sistemática. Os dados apresentados abaixo indicam que a melhora cognitiva depende do tipo de exercício (aeróbio ou anaeróbio), frequência e intensidade da prática, idade, além de outros fatores discutidos que poderiam influenciar ou não no desempenho cognitivo de todos aqueles estudados.

Palavras-Chave: cognição, atividade física, funções executivas

Introduction

Cognitive functions refers to the processing steps of information mediated by perception, learning, memory, attention, reasoning and the psychomotor functioning, which includes reaction time, movement and performance speed (Chodzko-Zajko & Moore, 1994; Suutama & Ruoppila, 1998). Those functions are essential to the execution of many everyday tasks. However, during senescence, some of those abilities, like memory, attention and reaction time are reduced (Van Boxtel et al., 1997), primarily due to disorders of neurotransmission systems (Özkaya et al., 2005). Moreover, other factors are also associated with increased risk of cognitive impairment, including, head trauma, genetic factors, dependence on tobacco and alcohol, nutrition, mental stress and physical inactivity (Antunes et al., 2006; Schuit, Feskens, Launer, & Kromhout, 2001).

Regular physical activity is considered a protective factor for the development of various diseases, including cardiovascular (Warburton, Nicol, & Bredin, 2006), type II diabetes (Sigal, Kenny, Wasserman, Castaneda-Sceppa, & White, 2006), and mental disorders such as depression (Strawbridge, Deleger, Roberts, & Kaplan, 2002), stress (Fox, 1999) and anxiety (Herring, O'Connor, & Dishman, 2010). Furthermore, low levels of physical activity among adolescents are associated with sleep problems and headaches (Ferron, Narring, Cauderay, & Michaud, 1999).

Regarding cognitive implications, practicing physical exercises and regular physical activities are described as factors associated with protection from cognitive decline, decreased neuronal loss, reduced motor deficits and dementia in the elderly, in addition to promoting neurogenesis and being an important component of preventive strategy against Alzheimer's Disease (Carro, Trejo, Busiguina, &

Torres-Aleman, 2001; Klintsova et al., 1998; Laurin, Verreault, Lindsay, MacPherson, & Rockwood, 2001; van Praag, Kempermann, & Gage, 1999).

Regarding memory, Mello, Boscolo, Esteves and Tufik (2005) pointed out that there are conflicting data about the effects of physical exercise on this cognitive function. Antunes et al. (2006) found out that the relation between physical exercises can interfere in the cognitive performance by being involved with: 1) increased levels of the neurotransmitters and changes in brain structures (this would be evidenced by the comparison of physically active x sedentary); 2) cognitive improvement observed in individuals with mental impairment (when compared to healthy ones); 3) limited improvement achieved by the elderly, due to a lower mental/attentional flexibility when compared to young individuals.

In this context it is also important to highlight differences between physical activity and physical exercise. Physical activity consists on any movement or action that requires energy expenditure. Physical exercise refers to a planned and repetitive physical activity programmed to improved health purposes and is associated with increased metabolism. These terms will often be used in accordance with these boundaries.

Thus, the aim of this paper is to review the effect of aerobic and resistance training in cognitive functions as well as to discuss some hypothesis involved in these changes.

Aerobic training

One of the main characteristics in aerobic training is the use of the body as a source of burning substrates responsible for energy distributed to the muscles during activity.

In a study assessing 132 individuals with ages between 24 and 76 years old who underwent a physical training three times a week, it was observed a strong correlation between VO_{2max} with visual and verbal memory and cognitive processing speed, but not between VO_{2max} and verbal fluency. Moreover, it was also observed that the greater the age, the lower the performance in cognitive tests (Van Boxtel et al., 1997).

Williams and Lord (1997) conducted a study with 187 older-adults women in which exercise sessions were conducted for approximately one hour, twice a week for 12 months. The sessions consisted of warming-up (5 minutes), conditioning (35 minutes), stretching (15 minutes) and relaxation (5-10 minutes). The authors observed significant improvements in the experimental group compared to the control in regards of the reaction time, memory span and welfare measures. Another work involving 87 sedentary seniors who also took part of the training for one year of aerobic training, detected a better memory performance in those who practiced physical exercises (Hill, Storandt, & Malley, 1993).

In a Brazilian study with a sample of 40 elderly women, the experimental group (n=23) was trained in a physical conditioning program of 60 minutes sessions, three times a week, for six months. Among the results presented, there was significant improvement in the experimental group compared to the control in verbal fluency, humor, temporal-spatial orientation, exact reasoning, focused attention, reaction speed, and in remote, immediate, operational and logical memories (Antunes, Santos, Heredia, Bueno, & Mello, 2001). The authors emphasized that the improvement of physiological and psychological functions were the result of a growing and progressive system of physical training. This idea is supported by (Etnier et al., 1997), who claim that acute exercise may have little impact on cognition, as opposed to training.

Regarding the exhaustion training in aerobic exercise, Hancock & McNaughton (1986) studied the visual processing of orienteering practitioners under fatigue effect and observed that the athletes' ability to perceive visual information was quite impaired when they were in exhaustion. However, the opposite effect occurred in the participants' short term memory, improving it significantly.

Resistance training

Although the vast majority of studies on the influence of physical exercise on cognition have been outlined from aerobic training, some of them explored the relation between resistance exercise and cognition. Although the vast majority of studies on the influence of exercise on cognition have been outlined from aerobic training, some of them explored the relation between resistance exercise and cognition. However, until recently, many had methodological problems with interventions for very short periods (Liu Ambrose & Donaldson, 2009). An example is the work of Perrig-Chiello, Perrig, Ehrsam, Staehelin, and Krings (1998) in which the authors studied the effect of resistance training once a week in cognitive function. The sample composed by 46 old-age individuals (23 participants in the experimental group) had resistance training on the course of eight weeks, made up of 10 minute warm-up and eight exercises on machines. The authors observed an association between the effect of training and self-care, which is related to the improvement of psychological well-being.

Another more recent study was conducted by Cassilhas et al. (2007) in which they studied 62 older people during 24 weeks of medium and high intensity resistance training, with the duration of one hour each, three times a week. The authors found significant improvement in memory and attention in the experimental group, but no differences were found in groups when the intensities of training were compared. This finding indicates that both the moderate and intense training show similar benefits in cognitive functioning.

Fleury, Bard, Jobin and Carrière (1981), exploring the effects of physical fatigue, subjected 31 men to three different experimental treatments: a) anaerobic short training, b) supramaximal anaerobic training, c) progressive effort training, partially anaerobic. The authors found no decrease in tasks of visual perception after strenuous exercise.

Regarding an acute session of resistance exercises, Changa and Etnier (2009) observed that this had a positive impact in some types of executive functions in middle-aged adults. Liu-Ambrose et al. (2008) found that among older adults with a history of falls, an individual training program performed at home and involving resistance training and balance on the course of six months improved executive functioning of the participants.

Comparison between aerobic training and resistance training

Some works have compared the impact of aerobic and resistance training. One of these studies was from Ozkaya et al. (2005) and was conducted with 36 adults with ages between 60 and 85 years-old, randomly distributed in three groups: control (sedentary), strength training and aerobic training. All participated in a three times a week training program during nine weeks. Although there haven't been found differences on functional fitness tests between aerobic and strength training, the results suggest that strength training may have facilitate information processing and cognition.

Pontifex, Hillman, Fernhall, Thompson, and Valentini (2009) studied the effects of acute sessions of resistance exercises and resistance in executive control of operational memory of 29 college young adults. The authors found smallers reaction times immediately or 30 minutes after a session of aerobic exercises, but this didn't happen after resistance exercises. On the other hand, some conflicting results were also found. Blumenthal and Madden (1988) investigated the mnemonic performance of 28 adult men divided into an aerobic exercise group who practiced running three times a week for 12 weeks and another who practiced strength training exercises for the same period. The authors observed no significant differences between the performance in memory tests depending on the type of exercise.

Psychobiological aspects

The practice of physical activity or exercises promotes a number of changes in the body and the action of physical exercise on cognitive function may occur directly or indirectly (Antunes et al. 2006). In this respect, some authors explain the improvements in cognition through hypotheses, such as the fact that the exercise improves cerebral circulation, changes the synthesis and degradation of neurotransmitters, reduces blood pressure levels of LDL and triglycerides, and inhibits platelet aggregation (McAuley & Rudolph, 1995).

Other hypotheses are intended to explain the improvements arising from the practice memory exercise through the release of catecholamines, vasopressin, ACTH and β-endorphin, as these substances are released during long-term moderate and intense physical exercises (Santos, Milano, & Rosat, 1998). In this Sense, Chiari, Mello, Rezeak, and Antunes (2010) also highlighted in relation to the duration, frequency or intensity of physical activity, that different combinations of exercises imply different results, however, in their review of the effect of exercise on memory, the authors report that there are not enough elements to such recommendations as the results are scarce and difficult to compare.

Brain-derived neurotrophic factor (BDNF) is a protein from the group of neurotrophins and one of the most studied substances in relation to physical activity. This nerve growth factor enhances the survival of nerve cells, enhancing learning and protection against cognitive decline in animals who exercise (Engesser-Cesar & Cotman, 2002). Furthermore, BDNF is a critical modulator of neurogenesis acting directly on neurons or by means of neurotransmitters, especially acetylcholine that activates a complex molecular cascade pre and post synaptic inducing synaptogenesis (List & Sorrentino, 2010). Cotman and Berchtold (2002) highlighted that in addition to promoting higher levels of BDNF, exercise also mobilizes gene expression that can benefit neuroplasticity, in addition to promoting brain function.

Another possible hypothesis to explain a better cognitive performance in relation to memory induced exercise is based on the fact in studies on IGF-1 (insulin growth-like factor 1). Animals that exercise show better brain uptake of IGF-1 than the sedentary (Nunez, Busiguina, & Torres-Aleman 2000). Moreover, the authors also found that IGF-1 increased the expression of BDNF in the hippocampus that is accumulated in brain cells. A number of previous studies related exercises and the role of IGF-1 in the brain as promoters of mnemonic performance and neuro.vascularization (Markowska, Mooney, & Sonntag, 1998; Radaka et al., 2001; Sonntag, Lynch, Cooney, & Hutchins, 1997).

Finally, FGF-2 (basic fibroblast growth factor), also from the family of growth factors, like IGF-1 and BDNF, has a critical importance on the growth of several types of neurons (Anderson, Dam, Lee, & Cotman, 1988; Baird, 1994; Gómez-Pinilla, Lee, & Cotman, 1992; Gómez-Pinilla, Vu, & Cotman, 1995; Grothe, Otto, & Unsicker, 1989). Furthermore, Gómez-Pinilla, So, and Kesslak (1998) highlighted that the intensification of physical activity or an intense training increases the FGF-2 factor, which is involved with the necessary molecular basis for the improvement of cognitive function (Akhavan et al., 2008; Garcia, Chen, Garza, Cotman, & Russo-

Neustadt, 2003; Koehl et al., 2008; Lorenz & Meston, 2012; Mello, Benetti, Cammarota, & Izquierdo, 2009; Russo-Neustadt, Alejandre, Garcia, Ivy, & Chen 2004; Wigal et al., 2003).

Table 1. *Main studies evaluating the role of physical activity on cognitive functions*

STUDY	SUSBTANCE	RESULTS
Mello et al. (2009)	ACTH	The exercise reversed memory deficits in animals exposed to the model maternal separation for 10 days. The authors suggest ACTH would be one of the altered substances in response to physical activity.
Koehl et al. (2008)	b-Endorphin	The increase of b-endorphins during physical exercise appears to be a critical factor for hippocampal neurogenesis in mice.
Garcia et al. (2003)	Serotonin -5-HT	During regular physical activity of rats, the serotonin system was hiperactivated and promoted the expression of BDNF in the hippocampus.
Lorenz & Meston (2012)	Serotonin -5-HT	Physical activity helped boost libido in women who used antidepressants.
Wigal et al. (2003)	Dopamine	Children with Attention Deficit Disorder / Hyperactivity who perform physical exercises showed cognitive improvement. However, the release of dopamine was lower than in the control group.
Akhavan et al. (2008)	Angiotensin II	Mice that were subjected to physical exercises for 5 days showed better performance on memory tasks. After this period, the receptors blocking of Angiotensin II in the hippocampus caused a deficit of the same tasks. The authors suggest the importance of angiotensin in cognitive performance.
Russo-Neustadt et al. (2004)	Noradrenaline	In conjunction with a physical activity for 14 days, a group of Wistar rats received the administration of citalopram (a selective inhibitor of serotonin reuptake) and another group of animals received Reboxetine (selective inhibitor and norepinephrine reuptake). The animals of this latter group expressed BDNF levels in the hippocampus greater than the first group.

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