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Effects of Physical Exercise on Cognitive Functioning and Wellbeing: Biological and Psychological Benefits

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Running head: *Effects of Physical Exercise on Cognitive Functioning and Wellbeing*
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Abstract: ***Every day, a new study is published heralding the benefits of physical fitness. Among these, some studies showed that physical activity done today can benefit cognitive function for decades down the road. They indicate that physical activity and fine-tuned motor skills during early ages of schooling benefit cognitive function and continue through every stage of our lives. Physical activity is a strong gene modulator that induces structural and functional changes in the brain, determining enormous benefit on both cognitive functioning and wellbeing. This concise review addresses the need for physical activity and its effect on healthy cognitive functioning and wellbeing. As in this globalized society, physical activity is undermined by giving importance to academics and accommodating more time for it to survive the stiff competition.***

Keywords: physical activity, cognitive function, fine-tuned motor skills, well being, globalized society, and stiff competition

1. Introduction

To understand how physical activity and physical exercise might affect cognition, it is important to have a general understanding of the structures and functions of the human brain and how those structures evolved. The study of human evolution reveals that the physical activity of our early ancestors essentially guided the development of the modern human body and mind.

Many evidences demonstrated that physical exercise (PE) affects brain plasticity, influencing cognition and wellbeing (Weinberg and Gould, 2015; for review see Fernandes et al., 2017). In fact, experimental and clinical studies have reported that PE induces structural and functional changes in the brain, determining enormous biological, and psychological benefits.

Before analyzing the benefits of PE, it is necessary to define PE precisely. Indeed, PE is a term often incorrectly used interchangeably with physical activity (PA) that is "any bodily movement produced by skeletal muscles that requires energy expenditure" (World Health Organization, 2010). Then, PA includes any motor behavior such as daily and leisure activities and it is considered a determinant lifestyle for general health status (Burkhalter and Hillman, 2011). Instead, PE is "a sub classification of PA that is planned, structured, repetitive, and has as a final or an intermediate objective. The improvement or maintenance of one or more components of physical fitness" (World Health Organization, 2010). Examples of PE are aerobic and anaerobic activity, characterized by a precise frequency, duration and intensity.

In the present brief review we focus on the relationship between physical exercise and cognitive functioning. The other aim of this work is to emphasize the role of physical exercise on brain health and wellbeing of the individual.

Effects of Physical Exercise on Brain structure, Brain Function and Cognition

The brain has a remarkable capacity for modifying its structure and function according to the influences of the environment and experience. Physical activity has played one of the most vital roles during biological adaptation and survival of the species through thousands of years, in a process in which the modern brain was developed. Neuroplasticity is an important feature of the nervous system, which can modify itself in response to experience (Bavelier and Neville, 2002). For this reason, PE may be considered as an enhancer environment factor promoting neuroplasticity.

Biological rationale for the effects of exercise on cognition

The Brain areas that change with physical activity are cerebellum, hippocampus, motor cortex and prefrontal cortex. The hippocampus, a structure that has a fundamental role in memory processing and learning is one of the main brain regions influenced by physical activity.In addition, development of brain regions that warrant energy efficiency such as the hypothalamus likely evolved with centres that control cognitive abilities, and this has introduced the concept of the "metabolic brain."Exercise leads to changes in neurons that control arousal and attention; increased levels of proteins that maintain brain health, the growth of new neurons in brain networks involved in learning and memory, and increased brain blood distribution (Hillman, Erickson, & Kramer, 2008).

Physical exercise and cognition in children

The ancient Greek philosopher Plato considered routine physical activity critical for children's education. As we progress from elementary to high school, our brains rapidly

develop structural and functional circuitry that support higher-level cognitive abilities, such as our ability to regulate and inhibit behaviour, multi-task, and resist distraction. Acute exercise produces temporary changes in children's physical arousal that affect thinking processes. Chronic exercise training produces structural changes in the brain and improvements in physical fitness. Both acute exercise and chronic exercise training benefit children's mental functioning - but in different ways. As children start moving, their heart and respiration rates increase; they become more aroused. Several studies have found that children's attention and learning improve immediately following physical activity that produces moderate levels of arousal (Tomporowski, 2003a). Studies that compare physically fit and less physically fit children consistently show differences in brain structure and processing speed, which highlights the benefits of routine physical activity (Chaddock, Pontifex, Hillman, & Kramer, 2011). The effects of the exercise programs on cognition were measured with a comprehensive test that provided measures of executive function, attention, spatial organization, and memory, and included a standardized test of academic achievement. The researchers discovered that exercise influenced specific measures of cognition and academic achievement.

Physical exercise and wellbeing

Over the last decade, there have been several extensive reviews of the exercise psychology literature, which offer positive support for the role that exercise play in the promotion of positive mental health.In a wide-ranging literature review, McAuley has considered the relation between exercise and both positive and negative psychological health. In common with other review articles, McAuley identifies the positive correlation between exercise and self-esteem, self-efficacy, psychological wellbeing, and cognitive functioning, and the negative correlation between exercise and anxiety, stress, and depression.

In children, PE is correlated with high levels of self-efficacy, tasks goal orientation, and perceived competence (Biddle et al., 2011). In youth and adulthood, most studies evidenced that PE is associated with better health outcomes, such as better mood and self-concept (Berger and Motl, 2001; Landers and Arent, 2001; Penedo and Dahn, 2005). In the aging population, PE helps maintaining independence (Stessman et al., 2009), favoring social relations and mental health.There are consistent evidences that PE has many benefits for people of any age, improving psychological wellbeing (Zubala et al., 2017) and quality of life (Penedo and Dahn, 2005; Windle et al., 2010; Table 1)

PE effects on psychological wellbeing	
Biological effects	Psychological benefits
Increased cerebral blood flow, maximal oxygen consumption and delivery of oxygen to cerebral tissue, reduction in muscle tension, increased serum concentrations of endocannabinoid receptors	PE decreases: anxiety, depression, dysfunctional and psychotic behaviors, hostility, tension, phobias, headaches
Cerebral structural changes, increased levels of neurotransmitters (e.g., serotonin, beta-endorphins)	PE increases: assertiveness, confidence, emotional stability, cognitive functioning, internal locus of control, positive body image, self-control, sexual satisfaction

It was now well accepted, that is the interaction between biological and psychological mechanisms linked to PE enhances the wellbeing (Penedo and Dahn, 2005). Biological mechanisms of beneficial effects of PE are mainly related to increase in cerebral blood flow and in maximal oxygen consumption, delivery of oxygen to cerebral tissue, reduction in muscle tension and to increased serum concentrations of endocannabinoid receptors (Thomas et al., 1989; Dietrich and McDaniel, 2004; Querido and Sheel, 2007; Gomes da Silva et al., 2010; Ferreira-Vieira et al., 2014). Moreover, neuroplasticity phenomena such as changes in neurotransmitters are recognized to affect wellbeing. For example, PE increases the levels of serotonin (Young, 2007; Korb et al., 2010) and the levels of beta-endorphins, such as an andamide (Fuss et al., 2015).

Psychological research evidenced that PE can even modulate the personality and the development of Self (Weinberg and Gould, 2015). Moreover, PE has been correlated with hardiness, a personality style that enables a person to withstand or cope with stressful situations (Weinberg and Gould, 2015).

Much of the existing literature on exercise and mental health has focused on changes in anxiety, depression, mood, self-esteem, and stress reactivity. Alongside these, for the purpose of this review it was decided also to examine some less frequently cited areas of research.

2. Depression

Depression is the most common type of mental illness and will be the second leading cause of disease by 2020 (Farioli-Vecchioli et al., 2018). Epidemiological studies have consistently reported benefits of PE on reductions in depression (Mammen and Faulkner, 2013) and anxiety (DeBoer et al., 2012). For example, it has been seen that individuals that practice PE regularly are less depressed or anxious than those who do not (De Moor et al., 2006), suggesting the use of exercise as a treatment for these illnesses (Carek et al., 2011).

Martinsen reviewed the literature dealing with the effects of exercise on patients diagnosed as suffering from clinical depression. Initially, he found that such patients tended to be physically sedentary and were characterised by a reduced physical work capacity compared with the general population. Although a number of studies stress the importance of using aerobic exercise in the treatment of clinical depression, Martinsen also found that those who continued to exercise regularly after termination of a one year training programme were found to have lower depression scores than those who were sedentary. In particular, it was concluded that acute and chronic exercise effectively reduced clinical depression (North et al., 1990).

Anxiety

To date, there have been many published reviews dealing with the anxiolytic effects of exercise and physical activity. One review concludes that regardless of anxiety measures taken (trait or state, behavioural, self report, physiological), or exercise regimen invoked (acute v chronic), the results point to a consistent link between exercise and anxiety reduction (Landers DM et al., 1994).According to recent research, even a single, five minute exercise bout may be sufficient to induce an anxiolytic effect (Landers DM et al., 1994; McAuley E et al., 1996; Tate AK and Petruzzello SJ 1995). In conclusion, the literature unequivocally supports the positive effects of exercise on anxiety, with short bursts of exercise appearing to be sufficient, and, in addition, the nature of the exercise does not appear to be crucial. As with depression, the most positive effects are noted among those who adhere to programmes for several months.

Stress Responsivity

A related literature has considered how exercise may protect against stress. The available research suggests that increases in physical condition or improved fitness are likely to facilitate the individual's capacity for dealing with stress (Fillingim RB and Blumenthal JA, 2003).

In conclusion, while it may be that aerobically fit individuals do show a reduced psychosocial stress response, the role that exercise can play is probably best described as preventive rather than corrective, and the stress response itself remains only partially understood.

Mood State

A meta-analysis by McDonald and Hodgdon (McDonald DG, Hodgdon JA. 1991) appeared to confirm a clear relation between exercise and positive moods, with significant effect sizes being shown for all six subscales of the POMS. These studies highlight the possibility that gains in physical fitness may operate independently of mood, and hence it may be possible to show physical fitness gains in the absence of mood effects and vice versa. In comparison, acute aerobic exercise has been shown to be associated with significant positive mood changes (Maroulakis M and Zervas Y, 1993).

Self esteem

In keeping with the other relations already examined, a positive link between exercise and self-esteem has been established and in turn this appears to be strongest among those whose self-esteem is low (McAuley E, 1994). A meta-analysis (Gruber JJ, 1986) that focused solely on self-esteem in young children found a greater effect size for aerobic activities.While these associations are interesting, the literature provides little guidance as to which forms of exercise may be beneficial to which types of self-esteem.

Addictive and unhealthy behaviours

PE has been widely evidenced to be an effective tool for treating several addictive and unhealthy behaviors. PE tends to reduce and prevent behaviors such as smoking, alcohol, and gambling, and to regulate the impulse for hunger and satiety (Vatansever-Ozen et al., 2011; Tiryaki-Sonmez et al., 2015). In this context, several studies evidenced substance abusers benefit from regular PE, that also helps increasing healthy behaviors (Giesen et al., 2015). It has been evidenced that regular PE reduces tobacco cravings and cigarette use (Haasova et al., 2013).

3. Conclusion

The evidence accumulated so far indicates that exercise is a strong promoter of cognitive health in humans.The active lifestyle of our early ancestors using locomotion and foraging may have demanded development of cognitive abilities for survival. In the modern age where industrialization has dramatically transformed lifestyle, it is ever more so important to realize the dependency that the brain holds on physical activity and healthy dietary choices. The mismatch between levels of physical activity and our genetics may, therefore, contribute to the prevalence of several metabolic diseases such as obesity (Booth FW et al., 2002; Wendorf. M and Goldfine ID, 1991) and derived metabolic dysfunctions such as type II diabetes, hypertension, and cardiovascular disease (Booth FW et al., 2002; Jung RT 1997; Must A, et al., 1999).

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