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EFFECTS OF PHYSICAL ACTIVITY ON COGNITIVE FUNCTIONING IN THE CONTEXT OF ACADEMIC ACHIEVEMENT: REVIEW

Taking into consideration results of empirical studies from the past few years, one can conclude that physical activity has a beneficial impact on our functioning across lifespan. Current trends in science allow us to look at this issue from a different perspective. An important area which has not been examined until recently in this context is a positive influence of physical exercise on cognitive functioning. It can manifest itself in the improvement of both basic cognitive functions, like memory and more complex processes such as reasoning and decision-making, and ultimately translate into intelligence, academic performance and social relationships. Attempts to explain this mechanism were so far focused on exercise physiology, neurological analysis and social context. In this review, we will try to bring the issue of effects of physical activity on cognitive functioning throughout life, with particular emphasis on its positive implications in the development of children and adolescents.

Key words: *physical activity, cognitive functions, academic achievement*

According to the latest statistical analyses (Oblacińska & Woynarowska, 2014), over the past few years an increase in obesity levels among children and adolescents can be observed. This trend is linked to a decreasing amount of physical activity and, consequently, to a deterioration of physical fitness level. Children with greater body weight are in poorer physical condition compared to their peers who are not overweight or obese ((Kubusiak-Słonina, Grzegorzczak & Mazur, 2012). This alarming statistical data indicate that the lack of physical activity during adolescence can have consequences on health in one's adulthood. Sedentary lifestyle impairs the cardiovascular system, increases the risk of type 2 diabetes and, in consequence, increases mortality linked to the aforementioned diseases (Schuler, Adams, & Goto, 2013). It is therefore aptly

recommended to perform vigorous exercise several times a week, irrespective of one's age. Already mere 15 minutes of physical effort a day, which constitutes the half of the recommended exercise time (Redberg et al., 2009), can have beneficial effects. In such instances, it is recommended to take up aerobic training, such as running, cycling or power walking.

Only recently has it been noticed that physical activity may also have other effects. According to a popular belief, exercise is thought of as an activity performed primarily for the benefit of one's physical health. Yet regular exercise routine affects not only one's somatic health, but also hers cognitive functioning. In addition, it changes the structure of human brain (Kramer & Erickson, 2007). In this review, we will attempt to answer



a question, whether this effect also translates into the level of academic achievement among children and adolescents.

Changes in cognitive functioning

There is a wealth of empirical studies proving a positive effect of physical activity on specific cognitive functions, such as the speed of processing information (Hillman et al. 2009) or efficiency of cognitive control ((Buck, Hillman & Castelli, 2008). In their study project which spanned a period of two years, Reynolds and Nicolson (2007) observed that children (also those with dyslexia) participating in the programme which included elements of physical activity such as balancing on one leg, climbing, taking walks, etc. showed an improvement in phonemic skills of their verbal working memory, were able to reduce their inattention and improved their scores in standardised tests of reading comprehension. This seems to suggest that not only workouts with elements of aerobic training can be beneficial. Introduction of a diverse set of exercises during a workout has a multidimensional impact on cognitive areas seemingly unrelated to the routine. In addition, a recent study conducted by Verschuren et al. (2007) found that a 45-minute original exercise training programme consisting of various aerobic exercises positively affects aerobic capacity, stamina and cognitive functioning in children with cerebral palsy. What is interesting in the study in question is the fact that the positive effects of the training last even up to 4 months after its completion. The results of the study may suggest an interactive character of both cognitive and physical trainings.

Potential explanation of effects of physical activity on cognitive functioning

In the contemporary literature there are three hypotheses explaining how physical activity can affect changes in cognitive functioning. The first one concerns the impact of increased physical effort on oxygen saturation in the blood (Kramer et al., 1999), which leads to angiogenesis (i.e. the

formation of new blood vessels) (Kleim, Cooper & Vandenberg, 2002) in the area responsible for executive functions. The second hypothesis suggests that exercise increase levels of neurotransmitters in the brain, such as serotonin and noradrenaline, which are support information processing (Kubesch et al., 2003; Winter et al., 2007; Winter, 2007; McMorris, 2008). Finally, the third hypothesis focuses on increased secretion of neurotrophins, which results from physical activity. These include brain derived neurotrophic factor (*BDNF*), insulin-like growth factors (*IGF-I*) and basic fibroblast growth factor (*bFGF*). These factors contribute to longevity of neurons, strengthen their structure and allow new dendrites to form on fully developed synapses (Schinder, 2000).

Physical activity and academic achievement

There have been numerous attempts aimed at outlining the issue of physical activity in the context of children and adolescent education. A close examination of studies focusing on the link between the number of physical education classes and students' academic achievement showed that increasing the number of physical education lessons in the curricula does not negatively affect students' grades (Shepard, 1997). On the other hand, according to Sibley and Etnier (2003), introducing additional physical education classes slightly improves verbal skills. Also, Trudeau and Shepard (2008) found in their study that introducing one additional hour of sport activities does not have a significant effect on primary school students' grades, but can contribute to their improved concentration, attention and proper behaviour in class.

Having reviewed 15 independent studies, Tomporowski et al. (2008) distinctly showed that an introduction of additional sports activities positively affects cognitive functioning, intelligence and academic achievement. They do however make an assumption that all the changes are caused by tasks, which are linked to executive functions. Tomporowski's review is complemented by an analysis performed by Keeley and Fox (2009), who



showed that exercises improving cardiovascular fitness may have a significant positive effect on cognitive functioning. They also point out that increasing the length of physical activities at the cost of other classes does not negatively affect academic performance. These findings are reflected in the conclusions of research conducted by the American Center for Disease Control and Prevention (2010).

In one of the more recent extensive studies (Best, 2010) it has been found that when introduced to the school curriculum, physical activities positively affect children and adolescents' grades. However, the effects are rather marginal and sometimes inconsistent. Having separated specific elements of physical training in the implemented programmes, it turned out that aerobic exercises do not have effect on performance related to solving tasks which demand good hand-eye coordination, but they play a significant part in the case of tasks demanding agility and multi-layered reasoning.

Nelson and Gordon-Larsen (2006) observed improved grades in students participating in physical education classes. It turned out that students who participated in additional sports activities five times a week received higher grades more often. Similar effect was observed in children performing vigorous cardiovascular exercises (Coe et al., 2006), and a study conducted by Miller et al. (2005) revealed that girls who trained sports had a higher grade average than the girls who did not.

It seems that the social aspect of physical activity would have an additional positive effect on academic achievement. Contrary to this assumption, it turned out that participating in team sports may have negative effects on students' grades. A study by Eitle and Eitle (2002) showed that boys who trained sports received better grades, except for those who went in for American football or basketball. In another study Eitle (2005) showed that group activities had negative impact on students' performance in maths and on their verbal skills. Crosonoe (2002) on the other hand found that complete neglect of sports activities, especially at puberty, may lead to poorer grades.

It is important not to restrict physical activities to classes included in the curriculum. Additional, extracurricular activity is crucial. In their study, Donnelly et al. (2009) proved that primary school students participating in additional sports activities performed better academically. Six- and seven-year-olds who took part in an additional 10-week long physical programme improved their spatial, mathematical and reading skills (Fredericks et al., 2006). Physical activity may also translate into socioeconomic status. This was suggested in a cohort study by Åberg (2009), which was performed on a group of 1.2 million young Swedish recruits born between 1950 and 1976 who were enlisted for military service. A cross-sectional analysis performed during recruitment indicated a positive correlation between the results of physical fitness tests and the results of intelligence tests measuring reasoning and verbal skills. Interestingly, later in their lives, the most physically fit men decided more often to pursue higher education and found themselves in a better material situation when compared to their less athletic colleagues. The study, which was performed on such a large group of young men, also allowed to note distinct positive relations between the level of cardiovascular fitness and cognitive functions.

Conclusions

Our review shows that a regular and adequately intensive physical effort positively affects not only physical, but also mental fitness in children and adolescents. Programmes aimed at increasing physical activity may serve as a tool for improving cognitive functioning. Additionally, increased physical activity may be used to support treatment of depression (Calfas & Taylor, 1994), stress (Norris, Carrol & Cochrane, 1992) or anxiety (Petruzzello, Landers, Hatfield, Kubitz & Salazar, 1991). Children who play sports display a higher self-esteem more often (Calfas & Taylor, 1994). This is particularly noticeable in children with disabilities (Gruber, 1986).

Therefore, developing a habit of regular exercise routine is such important in the case of young



people. This will have a positive effect on their habits in the future and will allow to minimize the negative effects of the onset of diseases related to aging and, ultimately, improve their quality of life.

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