# Physical Activity and Educational Achievement: insights from exercise

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## CHAPTER

# The Effect of Teaching Methodologies in Promoting Physical and Cognitive Development in Children

Patrizia Tortella & Guido Fumagalli

## Introduction

"Mens sana in corpore sano". This quote from the Roman poet Juvenal summarizes the common belief that a bond between physical health and cognition exists. Even though the link between "body and mind" has been one of the enduring legacies of "Some Thoughts Concerning Education" (the Locke's treatise on philosophy of education (Locke, 1996) that has provided the basis for future development of pedagogy as science), the scientific effort to demonstrate the reality of this connection has been slow to build up.

Indeed, the scientific literature on issues concerning physical activity has grown continuously only in the last decades and most of it was due to interest on health. A search on PubMed for the items "physical activity human" shows that in 1985 the number of published papers was 1366 but that increased up to 23353 in 2015. Within these numbers, the publications addressing "physical activity cognition" were just 32 in 1985 and 1026 in 2015. Based on this studies, a large consensus has been reached on the role of physical activity in reducing preventable and avoidable mortality and disability due to noncommunicable diseases, such as cardiovascular and chronic respiratory diseases, cancer, diabetes (Katzmarzyk, Church, Craig, & Bouchard, 2009; Tremblay, Colley, Saunders, Healy, & Owen, 2010). Accordingly, most of the international organizations concerned with health (WHO - World Health Organization WHO, NASPSPA - North American Society for Psychology of Sport and Physical Activity, AAP - American Academy of Pediatrics, AHA – American Heart Association) have published recommendations to encourage health by preventing sedentary behavior and promoting the practice of physical activity (Tremblay et al., 2012). On the contrary,

no clear recommendations (or no recommendation at all) have been issued for exploiting physical activity to stimulate cognition.

The interest in the relation between physical activity and cognition has started to grow when scientists first examined motor development. As stated by Karen Adolph (Adolph & Berger, 2015), the idea that development was mostly driven by the genetic program and “maturation” of brain and muscles had limited the scientific curiosity. It was only around the seventies that the role of the environment (at large) and experience were recognized as fundamental determinants of motor development.

Development is a continuous phenomenon that occurs mostly during the early years of human life. Indeed, the adult human being is continuously built on what had been layered during his/her own development and the early years of life are the most relevant and sensitive in this respect. Knowing how motor competences and other human capacities are built, and how this process reflects on adult life, implies that the center of the scientific interest must be shifted from adulthood to childhood. The shift has occurred only recently, as indicated by the still relatively low number of scientific publication found in MedLine for the item "physical activity children" in 2015 (over a total of 23353 items dedicated to physical activity, only 2839 concern children).

A growing mass of evidences has identified modes and determinants of motor development. The relationships between development of basic motor skills, motor competences and fitness call for consideration on the educational strategies that must be put in place to promote persistency of physically active life styles. In addition, the recognition that emotional and cognitive components accompany motor development (Stodden, et al., 2008), had provided the final push for the scientific interest on the links between physical activity and cognition. Accordingly, physical education adapted to children has emerged from the mud of the cultural "obviousness" that frequently hinders the development of scientific knowledge and the elaboration of evidence-based educational strategies.

In this chapter, we will analyse the recent indications emerging from the scientific literature linking physical activity and cognition. In particular, we will focus on executive functions, a group of interrelated and prefrontal cortex-linked processes relevant for school and social achievements; we will discuss how physical education may participate to promote executive functions along with motor development and health.

# The changing view on development and the link between motor activities and cognition

As mentioned above, the ‘maturational perspective’ of development dominated the first half of the XX century; development was considered an internal or innate process guided by a biological and genetic clock controlling maturation of the central nervous system and development of the musculoskeletal system (Gesell, 1933; Shirley, 1933). The adult/educator had mostly the role of the attending person, accompanying the child along the path of the new knowledge, with minimal methodological distinction between educational strategies for acquisition of cultural knowledges or motor competences. Cross-cultural studies have highlighted the differences in patterns of cultural and motor development in early childhood among populations from different parts of the world, and have been instrumental to modify the views on child development leading to the definition of the ‘ecological perspective’. As for many aspects of social sciences, the Bronfenbrenner’s bioecological theory has been dominant in guiding researches on motor development (Bronfenbrenner, 1979), which is now considered the result of the development of multiple and connected systems, each limited by constrains. Since constrains change during life, development is a life-long process.

The theoretical picture of child development predicted by the dynamical system theory proposed by Ester Thelen (Kamm, Thelen & Jensen, 1990) has relevant and practical implications. As development is dependent on experience and constrains, education becomes an important aspect and the role of teacher (professional and parents as well) needs to be reconsidered. Indeed, different behaviors of caregivers might influence different motor and cognitive development, as suggested by cross-cultural studies (Keller, 2007; Kolling et al., 2014; Yen-Tzu et al., 2008). The adult is not only the provider of conditions for new cultural and motor experiences; he/she must also comply with constrains and create the conditions that promote the increasing acquisition of skills and competences for each child/individual. In this integrated view, motor development becomes tightly integrated with the psychological, sociological and cognitive aspects of the subject life (Diamond, 2000, 2007, 2014). As pointed out by Kamm et al., (1990), the mind is firmly coupled with the body, and the development of motor competences involves psychological processes including individual perception of capacity (Stodden et al., 2008).

# Executive functions and physical activities

This new view of motor development has spurred interest on the links with cognition. The term has a very broad meaning yet in this review we will limit our analysis to executive functions, a set of cognitive processes mostly linked to the prefrontal cortex which have been found to be predictors of academic achievements (Blair & Razza, 2007; Huges & Ensor, 2008; Morrison et al., 2010).

Executive functions are a group of interrelated top-down mental processes responsible for selection, scheduling, coordination and monitoring of goal directed processes regulating perception, memory and action (Donnelly et al., 2016). Inhibitory control, working memory and cognitive flexibility are considered “high order” core functions used to build up reasoning, problem solving and planning (Collins & Koechlin, 2012, Diamond, 2013, Diamond & Ling, 2016; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Lunt et al., 2012; Miyake et al., 2000).

Inhibitory control is critical for social life, because it regulates the capability to wait and think before acting, to resist temptations, to resist doing illegal acts, to be able to stay focused. In a longitudinal study, children with a good level of inhibitory control (those able to wait their turn, more resistant to distractors, more persistent on tasks, less impulsive) on an age range between 3 and 11 years old, were found to be in better physical and mental health when checked 30 years later (Moffitt et al., 2011); they were also less likely to be overweight, to use drugs, to commit a crime; they earned more and were happier compared to children in the control group.

Working memory is important to hold information in our mind, to do one or more mental operations, to solve problems. Working memory and inhibitory control have been shown to predict math and reading competence from kindergarten to University (Borella, Carretti, & Pelgrina, 2010). Cognitive flexibility helps to approach problems, to change perspectives, to switch easily from a task to another.

Executive functions are relevant in every aspect of life (Diamond, 2013) and several studies have confirmed that they are predictive of social, professional and scholastic achievements (Blair & Razza, 2007; Huges & Ensor, 2008), mental (Baler & Volkow, 2006; Lui & Tannock, 2007) and physical health (Crescioni et al., 2011; Miller, Barnes,

& Beaver, 2011), wealth, and quality of life (Brown & Landgraf, 2010; Davis, Marra, Najafzadeh, & Lui-Ambrose, 2010). In this respect, high levels of executive functions appear to be better predictors than IQ or socioeconomic status.

A relevant aspect of executive functions is that their levels are not innate and can be improved from infants to elders (Kovács & Mehler, 2009; Williams & Lord, 1997). The interest has grown on possible modulators. Among these, physical activity has been thoroughly examined. In a recent extensive review of the literature, Donnelly et al., (2016) report that the majority of the published data suggest that cognitive functions, as well as brain structure, benefit from physical fitness and from the practice of physical activity; a lower level of consensus links physical activity with scholastic achievements. On the other hand, as pointed out by the authors of the review, most of the studies do not meet the methodological criteria that usually characterize clinical studies; among limitations, the most common appear to be: lack of randomization or lack of controls, low statistical power, low level of definition/characterization of inclusion criteria of participants, poor definition of physical practices, lack of double-blind approaches to data collection and management. In conclusion, new; larger and better designed studies are needed to define whether a clear and direct correlation between physical activity and executive functions really exists.

In a literature review produced by Adele Diamond (Diamond & Ling, 2016), the analysis aimed to identify patterns of physical activity and/or physical education that may positively influence development of executive functions. It appeared that these functions and motor competences share similar properties: for both i) transfer is limited (training a basic motor skill such as balance does not improve another basic skill such as running; similarly, training working memory does not improve self-control), ii) gains depend on the amount of time spent on practicing, iii) persistency is limited and requires continuous training/exercising and, iv) improvements are higher when initial competences are low. On the other hand, executive functions improvement is obtained when additional specific and more stringent criteria are met. First, the child must enjoy the activity he/she is doing and the gain in executive functions is dependent on the way the activity is presented and conducted; second, the activity must always be challenging to induce the cognitive improvement (not a requirement for most forms of resistance training). Thus the personal characteristics of both the educators,(responsible for how an activity is presented and conducted) and of the participants are relevant to induce benefits for both motor and cognitive functions.

Interesting information on the role of teaching methodology were provided by a study by Trulson (1986) where three groups of 13-17-year-old juvenile delinquents received 2 different trainings of Tae Kwon Do, a martial art, for 1 hour, 3 times a week for 6 months. The first group practiced a traditional version of the art, with emphasis on the psychological/philosophical aspects; the second group received a more modern instruction with no attention to those traditional aspects; while the third group did not practice the art at all. The results showed that only the first group obtained a positive outcome in executive functions, resulting in decreased aggressiveness, lowered anxiety, increased social adroitness and value orthodoxy. The second group instead showed an increased tendency toward delinquency. In a more recent study comparing one group of randomly selected preschool children trained in a traditional martial art and another group trained in school physical education, the authors (Lakes & Hoyt, 2004) found a greater capacity of self-regulation in children practicing martial arts than in those from the second group. This possibly indicates that martial arts could increase the learning of

children toward a higher self-awareness, an expanded ability to evaluate intentions and actions, and to a better adaptation to different life situations. Finally, additional data to be considered by educators suggests that a continuous increment in difficulty levels for one activity in association to high variety/level of cognitive engagement would benefit the development of both the motor competences and the executive functions (Blumenthal et al., 1989; Davis et al, 2011; Ericsson & Towne, 2010; Etnier, Nowell, Landers, & Sibley, 2006; Kramer & Erickson, 2007).

Executive functions are embedded in the prefrontal cortex and other interconnected regions (Aron, Behrens, Smith, Frank, & Poldrack, 2007). The functioning of these areas seems to be negatively modulated by conditions such as stress (Arnsten, 1998), sadness, solitude loneliness, poor health; Diamond & Ling (2016) suggest that conditions reducing these negative aspects may improve the mental processes. Indeed, beneficial influences could be achieved by situations that promote health and fitness (such as physical activities), social support (Cacioppo & Patrick, 2008), joy (Gable & Harmon-Jones, 2008; Hirt, Devers, & McCrea, 2008) and that satisfy emotional and physical needs (Jing, Zhang, Wolff, Bilkey, & Liu, 2013; Etnier et al., 2006).

Enjoyment of the activities performed, as well as self-confidence and self-efficacy, are also very important for the optimal functioning of mental processes (Bandura, 1994). Feeling confidence in our ability to succeed and trusting that through efforts we can improve, are key components for success. The same occurs when the subject feels that errors and failed attempts are learning opportunities. These are conditions that lead to successful improvement of motor and cognitive skills (Bandura, 1994; Murphy & Dweck, 2010). Self-confidence and feeling of self-efficacy, together with expectations, have a strong effect on capacity to accomplish a task (Good, Aronson, & Harder, 2008). Perception of competence is in relation to task difficulty (Eccles & Harold, 1991) and can influence the child engagement in physical activity (Stodden et al., 2008); positive perception leads to more engagement in the exercise with effects on amount, intensity and level of physical activity and thus, improvement of motor skill (Stodden et al., 2008). As suggested above, positive experiences are conditions for positively modulate executive functions as well.

# The role of educators in linking physical activity and executive functions

Both reviews from Donnelly et al., (2016) and Diamond and Ling (2016) emphasize the need for appropriate and stringent study design when addressing questions related to the link(s) between physical activity and executive functions. Even more relevant is the consideration that games based on movement can be important instrument to foster executive functions in children together with physical fitness. On this regard, it is vital for the educators to be able to create appropriate conditions for the development of both motor and executive functions.

An important aspect regarding the activities organized by educators is that they must meet the peculiar characteristics of each child. Indeed, it is the presence of appropriate and multiple conditions for practicing that affect level of competence and the personal perception of it (Goodway & Smith, 2005). It should also be considered that the level of motor competence is fundamental to predict present and future (in adulthood)

engagement in physical activities (Clark & Metcalfe, 2002; Haywood & Getchell, 2005; Malina, 1996).

Children's perception of competence encourages or discourages the practice of physical activity (Stodden, et al., 2008). Welk et al. (2010) suggest that the perceptions of competence overshadow the actual competence of a person. Self-efficacy and perception of competence thus emerge as important components of the learning process that drives a subject to reach new levels of competence. These aspects should receive attention when children are engaged in sports or games performed in groups or when a child is exposed to a challenging condition. This is the typical situation with traditional games/sports or, at school, when the educator defines the rules of the game/activity and expects all children to act as requested. In most cases, only part of the group will be able to perform as requested, leading to a separation in two subgroups: the successful ones will feel high level of competence and the others will be highly frustrated. The typical outcome of this condition is that the successful children will practice further and gain advantage from the physical activities, while the frustrated children will withdraw from the task (Tortella & Fumagalli, 2014).

As for executive functions, practice, training and motivation are fundamental to improve motor skill and acquire a motor competence (Clark & Metcalfe, 2002). The strategies to increase efficacy of practice and, in turn, perceived success and motivation have been investigated only recently. As stated above, development of both motor skills and level of executive functions occur when children are pushed to challenge with very difficult level of skills, near the limit of competence (Davis et al., 2011; Diamond, Barnett, Thomas, & Munro, 2007). This is a "learning condition" defined by Vygotsky (1986) as "zone of proximal development"; it is a situation that is beyond the "comfort space" of the subject, a level that can be reached only with a limited/little help from someone else.

The role of scaffolding by teachers and expert peers is fundamental in every child to promote the possibility to increase motor and cognitive skills, feel joy and pride during the activity, look for repetition and thus achieving consolidation of the skill. In a study with preschoolers attending a playground designed to promote their motor development (Tortella, Haga, Loras, Sigmunsson, & Fumagalli, 2016), we have demonstrated that a limited experience (1h/week for 10 weeks) on a difficult motor task with a program of structured activity in the Vygotsky's zone of proximal development, lead to improvement of both motor skills and executive functions (Tortella & Fumagalli, 2014; Tortella & Fumagalli, 2016); children not trained in zone of proximal development did not improve in motor and cognitive skills. Interestingly, the group of successful (scaffolded) children spontaneously continued to train by themselves outside the lesson, even after the initial negative results. Motivation was high in this group as indicated by their usual sentences during their autonomous trials: "I can. I know that if I train, I will learn".

The above example underscores the need that teachers individually regulate levels of scaffolding in order to give every child the opportunity to develop his/her motor competence. The contribution of Vygotsky's theory on our understanding of development of executive functions is very important. Working in the zone of proximal development, with scaffolding provided by the adult, is the appropriate condition to avoid boredom and to motivate children to improve (Davis et al., 2011; Diamond, 2007; Manjunath & Telles, 2001). Practical elaboration with translation of the theoretical key

issues in daily practice are present in “Tool of the mind” (Bodrova & Leong, 2007), a school program for enhancing executive functions.

The educator should also consider that the positive emotion of enjoyment is also a strong motivation to practice physical activity (Scanlan, Carpenter, Lobelm & Simons, 1993; Brustad, 1993); indeed, when a child has good actual motor competence and perception of competence (intrinsic motivation), he/she feels joy. Other elements to promote enjoyment during physical activities are: movement sensations, social recognition and interactions, feeling appreciated, making new friends and staying with friends (Wankel, & Kreisel, 1985a, 1985b).

Diamond (2000, 2007, 2014) suggests that the different components of the human being are interrelated with each other and recommends to examine the way a teacher communicates and relates to children as an important factor for the development of executive functions. The experiences of well-being at school together with the perceived emotional engagement in the peer group and the teacher-student interaction contribute to student’s perceived cognitive engagement and school achievement (Pietarinen, Soini,
& Pyhältö, 2014). The teacher’s instructional behavior and support (Skinner, Furrer, Marchand, & Kindermann, 2008) together with other components of the student/teacher relationship, contribute to student emotional and cognitive engagement, self-confidence in own abilities, future academic achievement and social and behavioral outcomes (Walg, & Holcombe, 2010; Li & Lerner, 2012; Huges & Kwok, 2006; Gest, Welsh, & Domitrovich, 2005). Preliminary data from a recent study on children engaged in a difficult task indicate that the combination of physical and emotional scaffold induced both motor skills and executive functions improvements, whereas physical scaffold alone improved motor skills but not executive functions (Tortella & Fumagalli, 2016).

A final consideration that should be taken into account when planning activities to increment motor skills and/or executive functions is that both are very task specific. From a teacher perspective, this indicates that learning objectives must be abundant and differentiated to cover the high spectrum of motor skills and executive functions. In addition, it may sometimes be difficult to design activities intended to lead to improvement of both types of skills. Clear understanding and definition of the teaching objectives and of the methods to tailor activities on individual properties of the child are thus prerequisite for new and modern teaching of physical education.

# Conclusions

The practice of physical activity is believed to lead to improvement of motor skills and competences with several beneficial effects on present and future health, as well on psychological constrains of the child. However, no extensive data are available on the relationships between changes induced by motor activities on motor skills and executive functions. On the other hand, the data that have been accumulating in the recent years indicate that the (psychological) conditions that lead to improvement of executive functions can be easily applied to the context of organized motor activities. Teaching methodologies of physical activity rather than the activity itself appear to be relevant to enhance this important set of cognitive processes. From the educational perspective and considering the appreciation that movement-based games have among children, these conclusions highlight the potential significance of a revisited physical education in scholastic curricula for all ages.

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