ATLANTIS PRESS

Advances in Social Science, Education and Humanities Research, volume 436

1st Borobudur International Symposium on Humanities, Economics and Social Sciences (BIS-HESS 2019)

The Impact of Physical Activity on Executive Functions Among Pre-schoolers

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ABSTRACT

Executive Functions (EF) are the ability of individuals to initiate, adapt, organize, monitor, and control information and behaviour processes. EF consists of three basic components, namely inhibition, working memory, and cognitive flexibility. Those three components play a crucial role in children's cognitive, behavioural and social emotional development as the aspects of children's school readiness. Through experimental research methods, this study examines the effect of physical exercise to improve executive functions components among preschool children. The subjects of this study were 132 children aged 5-7 years from three preschools in Magelang City. They were divided into three groups, namely the experiment group 1 who were given complex physical training (with cognitive involvement), the experimental group 2 with simple physical training (without cognitive involvement), and the control groups without any treatment. The two experimental groups were given two sessions of training per week during four weeks. The results of the study showed that complex physical activity had an effect on EF, specifically the inhibition and WM component. Children who were given complex physical activity showed an increase in inhibition test scores and WM that were higher than children who were given simple physical activity and who were not given physical activity. While simple physical activity just effects on WM. Physical activity, both complex and simple, did not affect to CF. In addition, the findings of this study also indicate that mother's education plays a role in increasing children's inhibition.

Keywords: *executive functions, physical activity, pre-schoolers*

1. INTRODUCTION

Executive Functions (EF) refers to a group of mental processes which are required someone to concentrate and pay attention. EF allows a person to mentally play with ideas; to think before making action; to find something new, to face unexpected challenges; to resist temptation; and to stay focused [1]. EF plays an important role in children's cognitive, behavioural and social development in which those are the main aspects of the children's readiness [2].

Currently, there is general agreement that executive functions are divided into three core components as found by [3], i.e. inhibition, working memory and set shifting [1], [3], [4]. Inhibition is the child's ability to control impulses, control attention, behaviour, thoughts, and / or emotions. Working memory (WM) is the ability to remember and process memories in the brain. Whereas cognitive flexibility (CF) is the ability to think creatively, the ability to see things from a different perspective, and quickly and flexibly adapt to changing situations. Through these three components, a higher level EF is built, such as reasoning, problem solving, and planning [1].

At preschool age, this EF ability must have begun to develop. Children must be able to control their behaviour, be able to plan simple things, be able to solve simple problems, and easily interact with other peers. When a child enters school age, the WM component can help a child keep information or instructions in mind during class activities and then use it to solve problems. In addition, the inhibition component can help children to focus on stimuli that are relevant to the task while working on problem solving tasks, and resistant to internal and external disturbances. Furthermore, these skills are important for practicing self-control, delay gratification, and cognitive and emotional adjustment [5]. These various skills are related to the domain of school readiness, the ability to control thoughts and actions, delay gratification associated with emotional maturity, and cognitive adjustment related to cognitive development and general knowledge. Similar research also explains that the ability of inhibition and attention shifting during preschool is related to verbal ability [5].

Therefore, it is necessary to have EF stimulation for pre-schoolers that is appropriate to their developmental characteristics. One of the EF stimulations that might be appropriate for the characteristics of pre-schoolers, which they like to move, is through physical activity.

Physical activity that affects EF is aerobic physical activity. Aerobic activities require adaptive and flexible play in new situations. Thus, EF assignments and aerobic activities place the same demands on cognition processes that give rise to flexible behaviour and decision making in new environments. Physical activity has been thought to spur physiological changes not only for health, but also for cognitive function [6].

One study that examined the impact of physical activity on EF in preschool children is study about impact of

coordinated exercise on EF in kindergarten children 6-7 years (average age 7 years). The results of this study indicate that coordinated physical exercise specifically benefits tasks that depend on the prefrontal cortex in the brains of immature kindergarten children, which with physical exercise increases the allocation of attentional resources and increases the efficiency of neurocognitive processes [7].

In contrast to previously research which distinguishes groups of subjects based on the intensity of the exercise provided, this study tries to determine the effect of different types of interventions related to physical activity given to EF components. In this study there are two different types of interventions, physical activities to improve children's fitness through simple physical activities for one group, and interventions in the form of physical activities that involve cognitive processes in their activities through physical activities with complex motor coordination for other groups. In this study, researchers considered it was important to control for other variables such as the child's age, mother's education, and family income.

2. METHODS

This study was designed using an experimental design to find out the effects of exercise treatment (complex and simple) on executive functions and school readiness of preschool children. The research design used in this study is the untreated control group design with dependent pre-test and post-test samples [8].

The subjects in this study were 132 kindergarten children who were aged 60 months - 84 months (M age = 69 months) in the city of Magelang. There are three groups in this study. First, groups that are given physical activity with complex motor coordination. Second, groups that are given physical activity with simple motor movements. Third, the control group, which was not given physical training. The number of subjects given complex physical activity as much 46 (boys=23; girls=23), subjects given simple physical activity as much 41 (boys =24; girls =17), and subjects without any physical activity as much 45 boys =22; girls=23).

In the first group, physical activity provided is a variety of complex motor movements in which the movements that are designed require the child's ability to control and regulate movements, to focus abilities, and remember previous movements to make subsequent movements. The movements provided also include various running, throwing, and jumping movements which are coordinated in complicated ways and are given targets and obstacles. In the second group, physical training will be given in the form of running, walking, throwing and jumping with simple movements, such as jogging, walking, throwing a ball, and jumping on two or one foot without targets or obstacles. The difference between the two experimental groups is the level of difficulty and repetition of the movements performed in each session. All equipment used in physical exercise is in accordance with the physical development of pre-schoolers. This physical exercise will be given at an intensity of 70-85% for 60 minutes (including heating and cooling). The exercises are done in the morning starting at seven before starting learning. Physical exercise begins with warm up, continues with core training, and ends with cooling down. To avoid boredom in children, training activities will be varied at each session. This physical exercise is given twice a week, for four weeks. This study was approved by the research ethics committee of the Faculty of Psychology, Gadjah Mada University number 1736 / SD PL.03.01 / IV / 2018.

EF in this study was measured using the EF test developed by Willoughby & Blair [9]. The inhibition ability was measured using the spatial conflict arrow test, WM capacity was measured using the pick the picture test, and CF / shifting was measured using something's the same.

Child's age is the chronological age of the child calculated in units of months. Data on the age of the child is obtained from the date of birth of children owned by the school. The age of the child is calculated from the month and year according to the date of birth until the time of the pre-test. Mother's education is obtained from the number of years she has taken the mother in attending formal education. Family income is the amount of income earned by parents (father and mother) every month in Rupiah. Data on family income is obtained through a questionnaire that is shared with parents through teachers. The data in this study were analysed using analysis of covariant (ancova) which was the pre-test as covariance. This was done to determine the difference in the impact of treatment from the three groups by considering the results of each pre-test.

3. RESULTS AND DISCUSSION

Based on Table 1 it can be seen that there was no difference in the average age in the three groups. Mother's education and family income in the group of subjects with simple physical activity is slightly higher compared to the group of complex physical activities and groups without physical activity.

Table 1 Data Description of Child's Age, Mother Education, and Family Income

PA	CA		ME		FI	
	M	*SD*	*M*	*SD*	*M*	*SD*
Complex	69	4.32	12.5	2.58	2528261	1687557
Simple	69	4.93	13	2.69	3139024	2133059
Control	69	5.68	12.8	2	2722222	1461302

PA: physical activity; CA: children's Age; ME: mother's education;
FI: family income; M: mean; SD: std. of deviation

Based on Table 2 it can be seen that there was an increase in mean of inhibition, WM, and CF in all three groups.

Table 2 Data Description of EF Components Pre-test and Post-test

PA		Inhibition		WM		CF	
		Pre	*Post*	*Pre*	*Post*	*Pre*	*Post*
Complex	M	28.59	33.83	22.52	25.3	9.98	13.13
	SD	5.36	3.49	3.96	2.41	2.66	1.75
Simple	M	27.93	31.22	23.95	25.76	10.68	13
	SD	7.06	5.73	3.21	2.5	3.16	2.69
Control	M	30.71	33.07	23.62	24.07	11	12,31
	SD	5.57	3.87	3.89	3.32	2.58	2.83

However, if seen in Table 3, only CF in the group that were covered in physical activity were complex, and WM in the group that was not given physical activity was significant.

Table 3 Results of Paired Sample Analysis T Test for Each EF Component in Each Group

Group	Comp.	M	SD	SE	t
Complex	In.	-2,80	10,55	1,56	-1,80
	WM	-2,60	13,55	2,00	-1,30
	CF	-3,25	9,99	1,47	-2,21*
Simple	In.	1,44	12,17	1,90	0,76
	WM	-0,95	9,67	1,51	-0,63
	CF	-0,30	15,54	2,43	-0,12
Control	In.	1,95	11,08	1,65	1,18
	WM	4,09	8,24	1,23	3,33**
	CF	3,62	12,60	1,88	1,93

*Comp: components; In.: inhibition; M: mean; SD: std. of deviation; SE: std. error; *:p<0,05; **:p<0,01*

Furthermore, to determine the effect of physical activity given and the role of each covariable, a covariate analysis was performed. The results of the analysis can be seen in Table 4.

Table 4 The Effect of Physical Activity and Covariable on EF Components

	Inhibition	WM	CF
Children Age	0,957	2,599	0,005
Mothers Education	4,444*	1,097	0,897
Family Income	0,581	1,300	0,479
Physical activity	4,734*	5,927**	2,082

**p<0,05; **p<0,01*

Based on Table 4 it is known that the child's age and family income are not related to changes in the value of each EF component after being given physical activity. Mother's education is known to play a role in increasing children's inhibition after treatment. Furthermore, it is known that there are differences in inhibiting and WM in each group. But there was no difference in CF in the three groups.

Table 5 Results of Pairwise Comparison Between Group Each EF Components

Comp.	PA		MD	SE
Inhibition	complex	simple	6,050*	1,97
		control	2,985	1,91
	simple	complex	-6,050*	1,97
		control	-3,065	1,99
WM	complex	simple	0,199	2,08
		control	6,068*	2,00
	simple	complex	-0,199	2,08
		control	5,869*	2,05
CF	complex	simple	1,378	2,17
		control	4,211	2,11
	simple	complex	-1,378	2,17
		control	2,833	2,15

Comp.: components; MD: mean difference; SE: std. error

Through Table 5 it can be seen that in inhibition, groups with complex physical activity are higher than groups who were given simple physical activity or those who were not given physical activity. Whereas in WM, the group with complex physical activity was higher than the group without physical activity, as well as the group who were given simple physical activity was better than the group without physical activity.

The results of this study indicate that EF stimulation through physical activity given in this study can increase EF especially in inhibition and WM components. This can be seen from the increase in the average value of subjects from pre-test to post-test, where subjects who were given complex physical activity experienced a higher increase in EF values and inhibitions, while subjects who were given simple physical activity experienced a higher increase in WM than subjects who were not given physical activity.

This research shows that complex physical activity can increase the ability of inhibition and WM in children. This is possible because the complex physical activity given in this study requires more of the child's ability to concentrate on listening to instructions / cues and focus on the target, and demands the child's ability to refrain from reacting too quickly. While the simple physical activity given in this study requires the child to remember the previous instructions, and relate them to the next movement, where the repetitions of movements in this simple physical activity is more than in complex physical activities. However, this activity has not been able to improve the CF component in children.

The lack of influence of physical activity on CF may be due to changes in rules and movements in each session that are less varied, which is not enough to demand the child's ability to adapt to changing situations. As explained earlier that CF is closely related to creative thinking, the ability to see things from different perspectives, and quickly and flexibly adapt to changing situations. In complex and simple physical activities, although the movements carried out vary in each session, there is no time when the child must design a movement of his own. Movement in complex physical activity has more to do with the child's ability to focus and control movements.

As explained earlier, that CF is built from inhibition and WM, and develops in individuals after the other two core components [10] [11], so that there is no influence of activity This physical effect on CF may also be caused by the undeveloped component, because the inhibition component and the WM are only just beginning to develop.

The findings of this study are in line with the physiological fitness hypothesis, or called the cardiovascular fitness hypothesis [12]. This theory explains that regular exercise will cause short and long-term changes in the brain area with an increase of cerebral blood flow that are important to support learning and memory. So, through physical activity, the children body experienced an escalation of blood flow to the brain which then activates the brain parts, especially those that regulate the ability to learn and memorize.

This study also supported the link between the physical fitness from routine physical activity and the escalation of cognitive abilities, especially the ability to focus on certain details, and the ability to remember and relate particular situations. It is similar to Gessel theory which states that when an individual has regular physical activities, it can help a nerve to be more mature to strengthen mental development. Considering that behaviour change is biologically controlled by nerve maturity. According to Piaget's cognitive theory, the physical and cognitive development is closely related. In this study, the children physical activity in each session helped to develop their motor skills so that the development of motor skills in children can improve their ability to explore and understand the environment that support other cognitive structures, such as attention and working memory abilities.

Based on the theory of children development, the pre-school age children love to play. The level of physical activity of children at pre-school age is higher than in later periods [13]. It causes an increase in the value of EF and its components after the given treatment. In this study, the stimulation of EF development in the form of physical activity is in accordance with the characteristics of the children development period. So, the subjects become more enthusiastic and actively involved in each session of the treatment.

This study also supports the findings that physical activity impact on EF among preschool children, which shows that coordinated physical exercise specifically benefits the tasks that depend on immature prefrontal cortex in the brain among kindergarten children [7]. This physical exercise increases the allocation of attitudinal sources and efficiency of neurocognitive processes. Furthermore, in this study, complex and simple physical activity carried out in a coordinated manner for four weeks showed a change in EF especially in the components of inhibition that are important in the attention process, as well as changes in WM which play an important role in the learning and memory process.

These results are consistent with previous findings, that one of the activities that can be given to children to improve their EF ability is through aerobic physical activity [14]–[16]. In this study the physical activity given to children is aerobic physical activity, which is physical activity that makes the heart work stronger and makes sweat come out.

Many studies have examined the effect of physical activity on EF in children, but few have examined it in pre-schoolers. Most of the research that has been done is testing the impact of physical activity on primary school children [17]–[21]. There is one study that examines the effect of physical activity on EF in pre-schoolers [7]. In contrast to the study, which distinguishes groups of subjects based on training intensity, this study tries to examine the effect of different types of physical activity interventions on the core components of EF. In this study there are two types of physical activity, involves complex motor coordination (cognitive engagement) and simple physical activity (without cognitive engagement).

The results of this study can be useful as a basis for developing health-based cognitive stimulation. This is because the physical activity designed in this study is part of the basic movements of the sport. Sports activities are very important for early childhood because by doing sports activities can improve physical fitness and improve the quality of organs including: heart, lung, blood circulation, energy metabolism, growth hormone, the immune system, and the exhaust system so that the physical and spiritual qualities of early childhood are getting better. Sports

activities that are good for develop early childhood characteristics, such as: (1) giving a variety of motion experiences (multilateral training) in the form of games and competitions; (2) stimulating the development of all five senses; (3) develop imagination / fantasy; and (4) moving to the beat / song and story [22].

This application for developing cognitive stimulation through physical activity is also part of the application of health education services. Early childhood health education is a key element in early childhood education and not only as a health learning process, but optimizes physical growth and cognitive and emotional potential to underlie the personality and intelligence character and main foundation in further education [23]. Therefore, the results of this study can be applied and developed as one of the stimulations for developing developmental aspects, especially cognitive aspects for early childhood in preschool.

The results of this study also showed that mother's education was related to the child's EF. This might happen because highly educated mothers will have more insight and concern for children's education. They will stimulate children through various activities that can improve children's academic abilities. The results of this study are similar to previous research that found that the level of parental education is very important in the cognitive development of children, especially in the development of EF [24]. This can happen because mothers with high education create an environment that stimulates the intellectual abilities of their children, they will use more vocabulary, and read more of their children [24], [25]. So, it is the interaction of mother and child that is likely to improve children's social and emotional skills.

In this study also not found any role of children's age on the ability of EF. This might be caused by their age variation that is not far adrift, which is five to six years. These results might be different when compared to children over the years.

Family income, also did not influence EF's ability and children's school readiness. This might occur because parents with high income in this study do not necessarily provide a variety of facilities that can improve children's cognitive abilities, or provide an environment that supports children's learning processes. Besides that, they also do not necessarily provide good and adequate nutrition for their children. The results of this study differ from the previous research that family income can predict the development of children's EF abilities [26]. This is because parental income is usually related to the level of health and nutritional needs that are important for the child's brain development. In addition, parental income is also related to the provision of an environment and learning tools that can improve children's intellectual abilities.

However, there were some limitations in this study, such as the given physical activity was only eight sessions (four weeks), the types of rules and movements were not varied enough, the physical activity required a large space. Furthermore, the impact of other variables that may also affect EF children such and in this article, we have not discussed the impact of other variables that might also affect EF children such as motivation, interest, and IQ of children had not been examined yet.

4. CONCLUSION

Based on the results of research and discussion, it can be concluded that physical activity, especially complex activity which involves motor and cognitive coordination, can be used as one of the stimulation models for the development of EF's abilities in pre-school children. However, this activity still needs to be developed so that all EF components can develop. Of course, the activity designed must be adapted to the physical and motoric development of the child, the child's health condition, and the physical condition and equipment owned by the school. So that the application of physical activity as a model for the development of EF children can be carried out smoothly according to purpose.

ACKNOWLEDGMENT

This research was funded by Directorate of Research and Community Service, The Ministry of Research, Technology and Higher Education through Doctoral Dissertation Research grant in 2017. The researchers would like to thank to all preschool students, teachers, and principals in Magelang City, as well as undergraduate students of Faculty of Teacher Education and Educational Sciences, Muhammadiyah University of Magelang who has participated in data collection of this study.

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