Original Article

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# The Acute Effects of Actively Play on the Executive Functions of Thai Children

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*Authors' Contribution: A – Study Design, B – Data Collection, C – Statistical Analysis, D – Manuscript Preparation, E – Funds Collection*

## Abstract

*Background:* This study aimed to investigate the effects of a single active play intervention on the executive functions in children. *Methods:* A quasi-experimental design. Children from two classrooms in the 5th grade were randomly selected. Children in one classroom (n=30) were assigned to an active playgroup, while those from another class (n=30) were assigned to a control group. We tested two components of executive functions (i.e., working memory [the Trails Making Test (TMT)] and inhibitory control [the Stoop Color-Word Test (SCWT)]) at pre-and post-intervention times. *Results:* There was a significant interaction effect of an active play by time for the TMT and SCWT ($p < 0.01$). At post-test, children in the active playgroup had better TMT and SCWT scores than those in the control group ($p < 0.05$). Compared to the pre-test, children in the active playgroup had better TMT and SCWT cores on the post-test ($p<0.01$), while children in the control group had better TMT1 and SCWT2 scores in the post-test (all $p<0.05$). *Conclusion:* Given the improved working memory and inhibitory control, the active play seems to be an effective intervention, even in a single bout.

**Keywords:** active play, working memory, inhibitory control, trail making test, stoop color-word test

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# INTRODUCTION

Physical activity is one important factor that contributes to brain development. Body movement increases the connections of nerve impulses in the brain, which is the same working process as reading, writing, or even thinking in mathematics. Also, different activities such as reading, calculating, or engaging in various physical activities stimulate brain functions in the same area [1]. Regular body movement results in the work of the nervous system that's used in problem-solving, language development, creativity, and physical growth. Movement stimulates the work of nerve cells and is related to memory and learning, as the brain is responsible for planning the movements of the body [2]. Engaging in regular physical activity improves learning and thinking skills [3], increases academic performance [4], is positively correlated with children's cognition [5], enhances cognitive development, and increases their executive functions [6].

Executive functions are important in unfamiliar situations, such as when children have to do some things they have never done before. In these contexts, executive functions will enable them to successfully manage and make decisions. Executive functions comprise three basic skills: 1) working memory, which means connecting the contexts, problem-solving, and decision-making, 2) Inhibitory control is an essential skill for children. Studies show that children who can control themselves well will try not to give up when faced with obstacles and that they have a greater chance of success in life, and 3) shift / cognitive flexibility involves when children encounter problems, and they can solve problems in a variety of ways. This also involves the ability to freely change focus from one activity to another and to do many things at the same time. The basic skills in all three areas affect one's emotional control, which is the appropriate expression of emotions, along with management-planning and organizing to set goals, to plan and prioritize tasks [7]. Executive functions are associated with behavior control [8], academic achievement [9], and sports [10]. Thus, increased executive functions at a young age are important to success in education and work, and one's health [11].

A survey of 243 Thai children aged 3-6 years in Bangkok and its vicinity found that approximately 18.5 percent of children had behavioral problems and impaired executive functions. It was found that those children had inhibitory problems (20.1%), followed by ones involving working memory (11.1%), emotional control (9.9%), planning/organizing (7.81%), and shift/cognition flexibility (5.35%), respectively [7]. Improved executive function in children is so important. Generally, physical activity can improve their knowledge, understanding, and memory [12]. Also, studies have demonstrated that skills involving calculation, reading, and physical education are positively correlated with one's physical-activity levels [13]. Increasing physical activity at moderate and vigorous-intensity during the day, without limiting one's study time, has proven effective [14].

A meta-analysis showed a significant effect of acute physical activity on executive functions [15]. However, the empirical evidence regarding the beneficial effects of cognitive involvement in physical activity vis a vis executive functions in children has been inconsistent and restricted [16]. Not all forms of physical activity can improve equally cognition [17]; physical activity features such as intensity, duration, and modality still need to be explored [17]. Two studies investigated cognitive flexibility, and one of them revealed the positive effects on cognitive performance [18]. The other showed no effects [19]. Another study found that some group games improved a more specific cognitive activation that further enhanced immediate memory performance. Specific cognitive activation occurred by having more social interaction and applying motor skills in a strategic fashion [20]. One study found that acute physical activity with high cognitive engagement can be more efficient than physical activity of the same intensity with low cognitive engagement [16]. Other studies have indicated that the degree to which physical activity requires complex, controlled, and adaptive cognition and movement may determine its impact on executive functions. The complex exercise was shown to have a stronger effect than the simpler exercise [21]. For example, acute treadmill walking did not affect shifting, a core executive-function component, in overweight children [22], and 20 minutes of stationary bicycling at moderate intensity, relative to watching a video for an equivalent period, did not facilitate adolescents' executive function [23]. On the other hand, some studies have pointed to the positive effects of acute treadmill walking on children's executive function [24]. Although these contradictory results are difficult to interpret, to date, it can be concluded that aerobic exercise can enhance executive function, and it may well be that exercise requiring greater cognitive engagement has a stronger effect on executive function than simpler exercises requiring limited cognitive engagement [21].

Active play is a form of play that aims to develop thinking skills for executive functions and is a physical activity that requires a cognitive function consisting of physical activities. It contains many forms of activities related to the functions of the brain and body - a total of four activities in which each activity can be divided into sub-activities that can be performed alone or in a group. This form of physical activity for brain development is a physical activity that stimulates the prefrontal cortex, which plays an important role in human cognitive development, is suitable for children of all ages and can be done by themselves at school or home, either outdoors or indoors, even in a very small area. However, it is unknown whether active play affects the child's executive function. Thus, our study aimed to investigate the impact of a single active play intervention on executive function in children.

# METHODS

*Participants*

Sixty boy and girl children (grade 5), aged 10.86±0.67 years, at an elementary school in Tak, were recruited from two classrooms for this study. A quasi-experimental design was used. Thirty children in the first class were assigned to an active playgroup. Another thirty children in a second class were assigned to a control group. The children who were assigned to the active playgroup had the opportunity to familiarize themselves with active play a week before testing. This accommodation period was important to eliminate any complications associated with unfamiliarity with active play. Children were taught to practice active play until they could do it themselves.

*Ethics*

All protocols were approved by the Human Subjects Institutional Review Board of Srinakharinwirot University (SWUEC/E-429/2561). Informed written consent was obtained from the parent/guardians of each child, while the children themselves gave verbal consent to participate in the study.

*Procedures*

On the day of testing, data on the background variables were gathered, such as their date of birth, height, and weight. Participants were asked not to engage in any PA before the measurement; teachers ensured that the children did not participate in physical education the day before. Two types of Trail Making Test (TMT) and Stoop Color-Word Test (SCWT) performance were measured before (the pre-test) and immediately after (the post-test) the intervention. Each test lasted about 3-5 minutes, including two short breaks of approximately 30 seconds. The participants were given a small gift and then sent back to class.

*Intervention and Instruments*

To measure the effect of active play on executive function, participants in the active playgroup were assigned to engage in such play for 40 minutes, while children in the control group were assigned to do their normal activities in the classroom for the same amount of time. Active play includes the following activities:

1. Rock, paper, and scissors activities involving the arms and hands. Kids extended one arm to the front, while the other arm was resting on the chest. For example, calling out *"hammer-paper*," the child extended his or her *right hand* to the front and moved it like *a hammer* (fist), while the *left arm* stayed on the chest and acted as *paper* (flat hand). Then, the child extended his or her *left hand* to the front and moved it like a *hammer* (fist), and the *right arm* moved to the chest and acted as *paper* (flat hand). Children repeated this ten times. The kids did *hammer-paper*, *hammer-scissors*, *paper-hammer*, *paper-scissors, scissors-paper, and scissors-hammer* in ten repetitions, alternating their left and right arms. This activity took about ten minutes.
2. Rock, paper, and scissors activities of the legs: We set to paper (the kids jumped and spread their legs and arms), scissors (they jumped and crossed their legs and stretched their arms forward), and hammer (they jumped and stood, while raising their arms above their head).

First, children matched with one-to-one, and each child did a rock-paper-scissors as he or she thinks. Rock defeated scissors, paper defeated rock, and rock defeated paper. Children were arranged to play rock-paper-scissors by starting with one other person, then two pairs, then five people, and then ten. When the boys and girls played as a team, they had to use the same posture and they tried to beat the other team. This activity also took about ten minutes.

3. The more you target, the faster you calculate. In this activity, we set the hammer to be equal to 10, the scissors as equal to 20, and the paper is equal to 50. Children matched with one-to-one and played rock-paper-scissors, then calculated the scores as soon as possible. For example, if the first child showed a hammer, and the other child showed paper, the number was 60. The child who answered correctly first was the winner. We assigned the activity starting from two, and then three, four, and five children per game. This activity took about ten minutes.
4. Move your left and right arms in different directions for ten minutes. The children moved their left and right arm in the specified position at the same time. The right arm did the activity as follows: 1) Stretched down and 2) Raised. The left-arm did the activity as follows: 1) Stretched down, 2) Spread arms, and 3) Raised. Both the right and left arms moved simultaneously, with the right arm doing rhythms 1 and 2 three times and the left arm doing rhythms 1, 2 and 3, twice, which was counted as one round. For the next round, the right arm would change to act as the left arm in the prior round, and the left arm acted like the right arm in the prior round.

*Trails-Making Test (TMT)* is commonly used in neuropsychological evaluations [25]. It is assumed to reflect a wide range of cognitive processes, including attention, visual searches and scanning, sequencing and moving, psychomotor speed, complexity, versatility, the ability to implement and change one's action plan, and to simultaneously sustain two trains of thought [26, 27]. From many versions of this test, Partington introduced two types [28]. In type A, the student must draw lines to connect circled numbers as quickly as possible in a numerical sequence (i.e. 1-2-3, etc.), without lifting the pen or pencil from the paper. In type B, the student must draw lines to connect circled numbers and letters as quickly as possible in an alternating numerical and alphabetical sequence (i.e., 1-A-2-B, etc.). The two types of TMT are made up of 25 circles spread over a sheet of paper. The circles in Part A are numbered from 1 to 25. The circles in Part B contain numbers (1 – 13), as well as letters (A – L). Start the time when students connected the "trail".

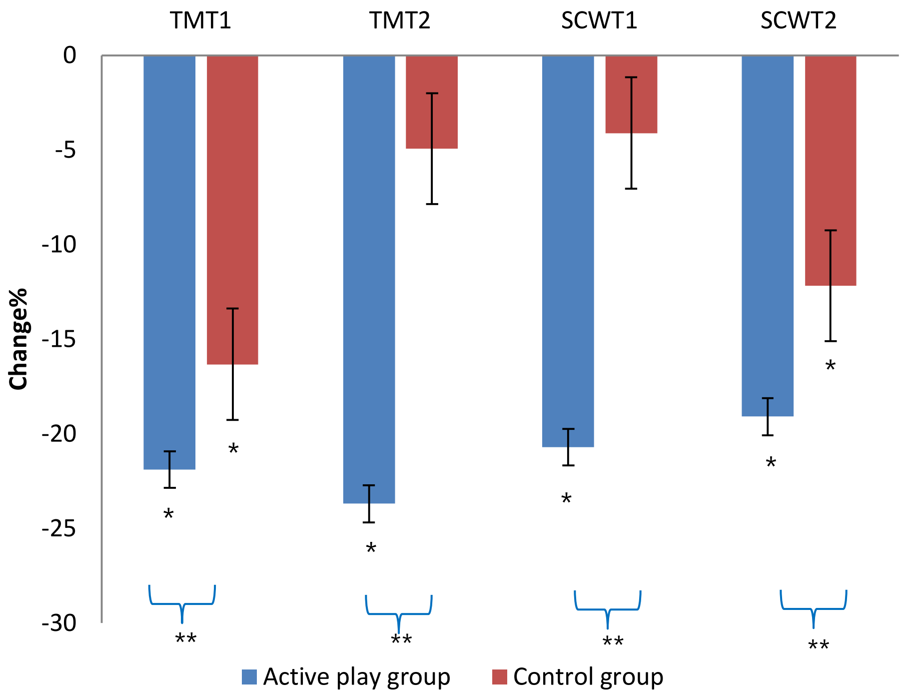
1 is a neuropsychological test that is commonly used to test one's cognitive-interference-inhibition capability [29]. It can be used to measure cognitive functions such as attention, processing speed, cognitive flexibility [30], and working memory [31]. Thus, it may be possible to use the SCWT to measure multiple cognitive functions [32]. To start the SCWT, students are required to name the ink color of a color word as quickly as possible. In Test 1, the color word is the same as the ink color's "congruent condition." In Test 2, the color word is not the same as the ink color (incongruent condition) [31]. For example, in test 1, the color word (e.g., red) is the same as the print color "RED (the print color is red)." Thus, the reaction time for naming the color print is very short. This is called "Stroop facilitation." Conversely, in test 2, color words are printed in inconsistently colored ink (e.g., the word "red" is printed in blue ink). When the color word [19] is not the same as the print color "RED (the print color is blue)," students are required to name the color of the ink, instead of reading the word. This is what's called an incongruent condition. Thus, the reaction time in naming the color greatly increases; most people slow down and take longer to say the word correctly. In other words, the participants are required to perform a less automated task (i.e., naming the ink color) while inhibiting the interference arising from a more automated task (i.e., reading the word) [33,34]. When students try to say the print color, it becomes very difficult to avoid reading the word. If the two bits of information conflict, the student's brain struggles to work out what the correct answer is, and it takes longer. This is commonly referred to as "Stroop interference" [29].

### *Data analysis*

Data analyses of the differences between and within groups were performed using SPSS version 21.0 for Windows (SPSS, Inc, Chicago, IL) software. The results regarding the measurements were provided with means and standard deviations. A test on the normality of the data was performed using the Shapiro-Wilk Test. Independent-sample *t*-tests were conducted to compare participants' demographic and physiologic characteristics. To assess the effects of active play and time on the TMT and SCWT, a fixed model multivariate analysis of the variance (MANOVA) with repeated measures was used. Significant interaction effects were followed up with Hotelling's $T^2$ and the one-way MANOVA with repeated measures. The level of significance for all statistical analyses was set at $\alpha < 0.05$. Since the correlations among the dependents' variable scores were moderately positive, it was appropriate to use the MANOVA [35].

# RESULTS

There were no significant differences between the active play and control groups regarding age (10.15±.36 vs. 10.64±.48), weight (40.67±11.78 vs. 39.13±11.58), and height (144.50±5.64 vs. 142.17±7.75). The mean and standard deviation of the TMT1 and TMT2 and SCWT1 & SCWT2 scores are presented in Table 1. The MANOVA showed that there was a significant interaction effect of active play by time for the TMT and SCWT, Hotelling's trace $F(4, 56.00) = 6.32$, $p = 0.00$. The Box's M test was significant $F(36, 11319.36) = 1.48$, $p = 0.031$. Hotelling's $T^2$ was used to follow up the interaction effect of active play by time for the TMT and SCWT. To compare between the groups, the test results showed that, at pre-test, students in the active play and control group had significant differences in their TMT and SCWT, Hotelling's trace $F(4, 57.00) = 1.77$, $p = 0.00$. The Box's M test was significant: $F(10, 17211.15) = 1.89$, $p = 0.041$. Thus, the pre-test scores were used as a covariate in the post-test comparisons between the groups. The Hotelling's $T^2$ showed that at, post-test, the active play group's scores were better than the control group's, Hotelling's trace $F(4, 51.00) = 2.48$, $p = 0.033$ (See Fig.1). To compare between the pre-test and post-test, one-way MANOVA with repeated measures showed that the active playgroup had better TMT and SCWT scores at the post-test when compared with the pre-test, Wilks's Lambda $F(4, 26.00) = 19.87$, $p = 0.00$. The control group's scores between the pre-test and post-test were significantly different on the TMT1 and SCWT2 (all, $p < 0.05$), but not on the TMT2 and SCWT1 ($p > 0.05$ (Figure 1).




* p < 0.05 for comparisons with the baseline; ** p < 0.05 for the comparisons with the control group

Figure 1. Mean Changes in TMT1, TMT2, SCWT1, and SCWT2.

Table 1. Mean and Standard Deviation of the TMT1, TMT2, SCWT1, and SCWT2.

| Variables [sec] | Active play Group | | Control Group | |
|---|---|---|---|---|
| | Pre-test M (±SD) | Post-test M (±SD) | Pre-test M (±SD) | Post-test M (±SD) |
| TMT<br>TMT2 | 41.94 (±13.71)<br>96.82 (±32.93) | 32.79 (±10.75)<br>73.89 (±25.92) | 42.83 (±13.42)<br>115.57 (±40.29) | 35.84 (±12.00)<br>109.87 (±39.69) |
| SCWT1<br>SCWT2 | 12.80 (±2.73)<br>27.05 (±6.99 | 10.15 (±2.25)<br>21.89 (±4.93) | 10.62 (±1.54)<br>30.38 (±8.70) | 10.18 (±1.74)<br>26.68 (±6.82) |

# DISCUSSION

Findings from this research demonstrate that 40 minutes of active play improved children's TMT and SCWT scores in the active playgroup more than in the control group. Our finding concerning the effect of active play on executive functions in elementary school students agrees with the evidence from the previous laboratory and school-based research indicating that short periods of individual physical activity enhance the cognitive test output of children, especially when they are evaluated for speed and accuracy [12]. Active play in this study involved skilled and complex movement and contained meta-cognition, such as connecting, problem-solving, and decision-making. Improving these skills with active play can stimulate children to enhance their working memory when they are taking tests. Similarly, during participation in active play, children can improve their self-regulation skills, such as understanding and controlling their thoughts, emotions, and actions. This can increase their inhibitory control when they are taking a test and when they encounter problems during a test, they can solve them better [7].

A previous study reported the associations between physical activity and academic performance [36]. Significantly, high doses of physical activity (i.e., 40 minutes) produced significantly better cognitive performance than after lower doses. [37]. However, light to moderate physical activity has been shown to transiently increase cognitive performance following a single, 20-minute bout of physical activity [38]. That study corresponds with ours, in that active play involving many movements at light to moderate intensity, practiced for 40 minutes, with continuous movement, can improve the executive function in children. It has been suggested that activities which involve both exercise and character development (e.g., traditional martial arts) or activities that involve exercise and mindfulness are most effective in improving one's executive function (i.e., working memory, cognitive inhibitory control, and emotional regulation) [39]. In our study, when children were engaged in active play, they had to move in a special and different direction and simultaneously had to think, plan, create, and solve a problem by themselves and with their peers. Thus, these skills improved children's executive functions, and this positive effect carried over during their taking of tests.

To explain how acute, active play can increase executive function, we may focus on general physiological changes (e.g., increased blood flow) and specific changes in the brain. Acute active play may promote an immediate neurochemical response that can enhance one's cognitive performance. There is evidence that exercise in a cognitively-engaging context has a stronger impact on the brain. An exercise that affects executive functions through multiple pathways has a stronger effect than exercise that works through fewer pathways [21]. Thus, active play (in this study) which affected executive function by many pathways (i.e., goal-directed thinking and skilled and complex movement) can increase a child's TMT (i.e., working memory) and SCWT (i.e., inhibitory control).

# LIMITATIONS

We did not use random sampling. However, this was due to the need to control children in a normal environment in which they did activities in their classrooms. Inactive play, we did not have control over the intensity of the kids' play. We controlled only the practice time, which corresponded to that of the normal 50-minute class and then the lunch break.

# IMPLICATIONS

Many schools, especially in Thailand, value the development of academic excellence through a focus on classroom learning, without realizing that physical activity can also enhance students' thinking ability and problem-solving skills. Our study shows that active play improves children's executive functions after their actual playtime. Active play is essential for brain development and academic learning. Schools should have a policy whereby such play is part of the girls' and boys' daily education. There should be a physical activity time before some class studies. For example, children do active play to improve their working memory, cognitive inhibitory control, and emotional regulation before they start the class in which they have to use thinking, planning, and problem-solving, such as in mathematics, physics, chemistry classes, etc. Further studies will shed light on this very important aspect of learning among children.

# COMPETING INTERESTS

The authors declare that they have no competing interests.

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