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Efficacy of physical activity training in comparison to the mental training in preadolescent's attention.

Afnan Alkhateeb[1*], Wasayf Aljohani[1], Bashayer Alsayegh[1], Asma Alonazi[2] Rasha Hegazy[3]

[1]Department of Physical Therapy, College of Applied Medical Sciences, King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia

[2]Department of Physical Therapy and Health Rehabilitation, College of Applied Medical Sciences, Majmaah University, Riyadh, Kingdom of Saudi Arabia

[3]Department of Physical Therapy for Neurological disorders and its surgeries, Faculty of Physical Therapy, Cairo University, Giza, Egypt

Abstract

Background: Comparing the impact of Physical Activity (PA) with Mental Training (MT) on school-age children's attention level.
Methods: A randomized control trial study was conducted at a primary school in Jeddah, Saudi Arabia. Sixty participants (aged 6-9 years) were divided into two intervention programs, with eight sessions over four weeks. The PA program lasted for 40 minutes and included moderate-intensity aerobic exercises, strengthening exercises, and balance. The MT program provided 3-4 exercises per session that lasted 20-30 minutes. Flanker tests and questionnaires were used to assess attention.
Results: A significant difference was found in children's attention after the PA ($p<0.001$) and the MT program ($p<0.05$). However, there were no significant differences in the number of errors or time taken following the PA and MT programs ($p>0.05$). Also, a significant negative correlation was found between number of errors and time taken in solving the flanker test, and with the age in the PA group ($r=-0.534$, $p=0.002$; $r=-0.605$, $p=<0.001$) and in the MT group ($r=-0.491$, $p=0.001$; $r=0.462$, $p=0.01$).
Conclusion: Physical activity with mental training exercise improves children's attention level, sleep quality, academic performance, and addiction to electronic devices after applying the intervention.

Keywords: Physical activity, Mental training, Attention, School age children.

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Introduction

Nowadays, children spend a great deal of time engaging in sedentary behavior. They spend more than half a day after school in sedentary activities, such as watching television, using computers or smartphones, and playing video games [1]. This sedentary lifestyle leads to them neglecting physical activity, putting them at a high risk of weight gain, delayed cognitive development, decreased academic performance, low self-esteem, and further psychological problems [2].

The critical period of cognitive development is during childhood. Cognitive functions are served by the Central Nervous System (CNS), including processing speed, memory, executive function, and attention [3]. Attention has been defined as the ability to focus on a specific input for some time without distraction by instantaneously suppressing irrelevant or distracting information parks [4]. Many factors influence attention, such as time spent watching screens and poor sleep quality, which leads to deficits in cognitive performance [5,6]. For example, a study found that children who watch television at the age of 1-3 years had a markedly increased risk of attention problems at the age of seven [6].

Although it is evident that performing any Physical Activity (PA) is beneficial to physical and mental health. The relationship between PA and improving cognitive functions requires further study [7]. Previous studies have examined the relationship between exercising and cognitive function in children [8]. Some have found a positive influence, particularly on executive functions, which develop intensively in childhood [9]. One study showed the positive impact of exercise-induced increases in oxyhemoglobin levels, which enhance the operation of executive functions [10]. However, the effects of PA on cognitive processes remain unknown. Many mechanisms have been proposed to explain how PA can help to improve mental function in humans [11]. One possible explanation is that aerobic exercise may increase physiological arousal in the reticular activating system and ascending stimulation to the prefrontal cortex, resulting in improved cognitive functions, especially attention [12]. Another possibility is that as vigorous PA arouses neurotransmitters, either epinephrine or dopamine, this enhances the synthesis of catecholamines that, in turn, enhances cognitive processing [13]. Finally, improved cognitive function may result from the cardiovascular fitness improvement that occurs through regular aerobic exercise, due

to an increase in cerebral blood flow [14]. PA interventions result in vascular changes, including increases in oxygen saturation and increases cerebral blood flow that, in turn, stimulate neurogenesis, which improves cognitive efficacy [15].

Cognitive training by paper and pencil puzzles, digital games, and the combination of stimulate memory, processing, and attention, demonstrated by Electroencephalogram (EEG) and Functional Magnetic Resonance Imaging (FMRI) [16]. Moreover, long-term training studies have shown that brain-training games can develop executive function, working memory, and processing speed. Besides, such games may increase cognition by recruiting the prefrontal cortex to complete the task, thus enhancing cerebral hemodynamics [17].

This study aimed to investigate the impact of Physical Activity (PA) and Mental Training (MT) programs on school-age children's attention level and compare both training programs' effects.

Methods

Study design

A randomized trial was conducted for four weeks, involving PA or MT for two days per week. The participants screened at the baseline for inclusion and exclusion criteria purposes.

Participants

This study was performed at Dar Al-Huda primary school in Jeddah, Saudi Arabia. This school was chosen because it includes both girls and boys. Sixty participants (34 boys and 26 girls, aged 6-9 years) volunteered to participate in this study. They were divided between two intervention programs, involving eight sessions delivered over four weeks for each group. Thirty students from the first and second grades (girls), and third grade (boys), were randomly allocated by the school administrators to participate in recreational school activities.

On the other hand, first and second-grade students (boys) and third grade (girls) were selected to participate in mental activities at home. King Abdulaziz university's Institutional Review Board (IRB) approved this study. The research team provided an explanation of the study to the participants and their parents. Then, parents and their children provided written informed consent and assent. The participants were chosen according to the inclusion and exclusion criteria.

Inclusion criteria: Healthy children without any physical or mental disability.

Exclusion criteria: Participants with cardiopulmonary conditions such as asthma, or major musculoskeletal injuries during the last six months, diabetes mellitus type 1 or 2, uncorrected visual problems, or other health issues that would interfere with the participants' safety during exercise.

Outcome

For the PA group, we designed an exercise program using different tools to be more attractive and challenging for children, such as small balls, balloons, hula hoop rings, obstacles, and ropes. We provided a booklet of mental exercises for the MT group, using mental exercises from two books, development of the intelligence of your child and the big book of brain games [18]. Additionally, the children's attention was measured using the Erikson flanker test with added fish, developed by Erikson and Erikson in 1974 [19].

Study procedures

After parents provided consent, a questionnaire was distributed on two occasions: at baseline before starting the exercise and after the four weeks of intervention. The questionnaires consisted of five sections. The first one, with three questions, comprised general information such as gender, age, the child's physical activity, and how often the child exercises. The second, with 15 questions, focused on the child's attention, with questions such as "Do they get distracted easily?" and "Do they often lose their necessary objects (school tools, books)?" The third had seven questions focusing on the quality of sleep, such as "Does the child go to bed at the same time every night?" and "Does the child wake up during sleep (intermittent sleep)?". The fourth had eight questions focused on addiction to electronic devices, such as how many hours the child spends on appliances a day and does the child prefers to play on an electronic game (e.g., tablet) rather than playing with his/her friends. The fifth had one question focused on academic class participation, exam performance, and concentration in class.

In the school's computer laboratory, the Flanker test with fish was administered under the teachers' supervision to measure the child's attention [19]. The test was performed twice before doing the exercise, then after four weeks of training. Five fishes were in the test, while the child had to focus on one fish in the middle. The fish's direction was either left or right and the children had to press the keyboard selection button. Arrows were drawn on the keyboard to be more evident for the children. The other fishes were either looking in the same direction (compatible) or the opposite direction (incompatible) than the middle fish. The fishes' direction was changed whenever the child started a new test trial.

The PA training program was administered by two skilled physiotherapists and one physical education teacher. The safety of the children was caution by the trainers. The session lasted 40 minutes, including moderate-intensity aerobic exercises, strengthening exercises, and balance. The range of intensity of aerobic exercise was selected to be moderate as the optimal results of cognitive functions occur at 60%-70% of the maximum heart rate, *i.e.,* at moderate intensity [20]. The first five minutes comprised a warm-up, and the last five minutes were a cool-down. The warm-up included a long stretch for leg and arm muscles. The physical program exercises were changed every day in terms of difficulty.

The home MT program was supervised by the parent using the instructions in the booklet. For example, parents were asked to administer the exercises twice a week, ensure that the child tries to find the solution on his or her own, and help only if necessary. The provided booklet contained 16 pages divided over eight days and three to four exercises per day. These exercises varied in difficulty, from moderate to severe, and each selected exercise tested the child's attention level. The session took about 20-30 minutes. The booklet included exercises of varying difficulty, from moderate to severe. We followed up with the mothers in a WhatsApp group weekly to ensure that they were trained twice per week [21].

Statistical analysis

Data collected comprised of participants' demographic information, questionnaires, and the flanker test. Outcome measures were coded, entered, and analyzed using Microsoft Excel software. Data were then imported into the Statistical Package for the Social Sciences (SPSS version 20.0) software for analysis. The data showed a normal distribution, according to the Shapiro–Wilk test. A result was considered statistically significant when p was <0.05 [22].

Means ± SDs calculated, and a chi-square test (X^2) and fisher's exact tests were performed to test for differences and associations among the questionnaires and flanker test variables for age, weight, height, and gender. Differences between PA and MT groups were examined by t-test or Mann Whitney. A chi-square test was used to test the association variables (questionnaires and flanker test) for categorical data (age, weight, height, gender). A result was considered statistically significant when $p<0.05$. Spearman's correlation coefficient evaluated the linear association between the two quantitative variables of age and gender with PA and MT [23].

Results

Demographic data and clinical characteristics of the children

The sample was divided into the PA (n=30) and MT (n=30) groups, with no significant difference in age between the two groups ($p>0.05$). PA group ages ranged from six to 9 years, with a mean ± SD of 7.53 ± 0.86 years, while in the MT activity group, ages also ranged from six to 9 years, with a mean ± SD of 7.3 ± 0.75 years [24].

Concerning the gender distribution of the children, 18 (60%) were boys, and 12 (40%) were girls in the PA group compared to 16 (53.3%) boys and 14 (46.7%) girls in the MT activity group, with no significant difference ($p>0.05$).

Effect of the physical activity program on children

Comparing the results of the flanker test score before and after the PA training program, there was a significant reduction in the number of errors ($p=<0.001$; Table 1). Also, there was a significant reduction in the time taken ($p=<0.001$).

Physical activity program	Pre	Post	Wilcoxon signed ranks test	p
No. of error (Mean ± SD)	5.6 ± 8.9	1.7 ± 3.35	-3.526	0.000 (HS)
Range	(0-41)	(0-18)		
No. of slow (Mean ± SD)	11.75 ± 1.7	9.3 ± 2.0	-3.582	0.000 (HS)
Range	(0-23)	(0-14)		

Table 1. Effect of the Physical Activity (PA) program on children before and after the intervention (flanker score). HS: Highly Significant difference (*i.e.* $p<0.001$).

Significant negative correlations were found between the number of errors and time taken, and the age of the PA group children ($r=-0.534$, $p=0.002$; $r=-0.605$, $p<0.001$) respectively. In comparing the PT and MT programs' results, no significant difference was found following the programs in either the number of errors or the time taken ($p>0.05$) (Table 2).

Effect of the MT program on children

Comparing the results of the flanker test scores before and after the MT program, a significant decrease was found in the number of errors ($p<0.05$). Also, there was a significant reduction in the time taken before and after the MT program

Mental training	Pre	Post	Wilcoxon signed ranks test	P value
No. of error (Mean ± SD)	5.2 ± 6.36	2.7 ± 4.1	-2.721	0.01 (S)
Range	(0-23)	(0-15)		
No. of slowness (Mean ± SD)	2.1 ± 3.4	1.1 ± 2.01	-2.395	0.01 (S)
Range	(0-13)	(0-9)		

Table 2. Effect of the Mental Training (MT) program on children before and after the intervention (Flanker Score). S: Significant difference (*i.e.* $p<0.05$).

Significant negative correlations were found between the number of errors and the time taken in solving the flanker test, and the age of the children who received the MT ($r=-0.491$, $p=0.001$; $r=-0.462$, $p=0.01$, respectively).

Also, there was no significant correlation between the two types of training programs, neither PA nor MT, and with the gender, PA ($r=0.150$, $p=0.254$), ($r=0.263$, $p=0.160$).

The sign test results used to analyze the questionnaire showed a significant improvement in attention from both training programs ($p<0.01$ in both cases). Moreover, there were significant improvements in the children's PA levels, how often they exercised per week, sleep quality, academic level, and addiction to electronic devices ($p<0.01$ in all cases). Additionally, as rated by their mothers, 53.3% of the children had positive changes, and 18.3% probably had positive changes after the programs.

Discussion

In the present study, we attempted to determine the cognitive effects of participating in PA or MT programs, specifically on selective attention.

In the PA training group, our present study demonstrated a reduction in errors and time taken on the flanker test. These findings matched with Hillman et al. who strongly recommended PA programs to enhance cognition and brain health status, especially in tasks that required executive control in preadolescent children of between 7-9 years [25].

Moreover, this current study demonstrated positive acute effects of moderate-intensity aerobic exercise on selective attention. These results in accordance with the findings of Chang et al. who investigated the acute effects of moderate-intensity aerobic exercise on cognitive performance and demonstrated a dose-dependent effect [26].

The positive effect of the PA training program on errors and task time may be attributed to the application of the moderate-intensity aerobic exercises [27]. Previous research found that moderate-intensity exercise improved hemodynamics by increasing the blood flow to the CNS, hence improving neurological functioning, specifically of the reticular activating system and the prefrontal cortex, which are responsible for arousal and attention.

Concerning the effect of regular anaerobic exercising through the PA training program, there was an improvement in physical fitness and maintenance of a healthy lifestyle that positively impacted neurocognitive function, cognitive ability, and academic achievement.

These findings concur with those of de Greeff et al. who found acute PA improved attention, while longitudinal PA programs also positively affected executive functions, attention, and academic performance [28].

The present study demonstrated a strong effect of PA training programs on the children's academic performance in conforming to the study by Jiang et al. who confirmed the positive impact of neurocognitive training on children's academic performance with attention deficits [29]. Moreover, our findings concurred with those of Kvalø et al. who examined the relationship between aerobic fitness and academic performance and documented the indirect effect of executive function on the positive relationship between aerobic fitness and mathematics achievement [30].

The findings supported the positive effect of PA training programs on the children's academic performance, which was in contrast to Donnelly et al. who suggested that PA training and physical education had no effects on academic achievement [31]. Our study showed positive effects of the MT intervention on the errors and time taken, indicating improvements in children's attention, which was supported by Lutz et al. who found that MT could significantly affect attention and brain function [32]. Moreover, a systematic review has summarized the cognitive skills that improved after mental training program through commercial or non-commercial video games and mental training programs [30]. However, those video games were mostly adventure games, which differ from the content of the Flanker test.

The Flanker score findings in the MT group, who showed noticeable improvements in attention, were not in agreement with those of a meta-analysis [33]. That studied the efficacy of cognitive training programs in children and adolescents. This meta-analysis showed that the overall effects of cognitive training on attention and executive function were consistently small, which could be due to the specific characteristics of the training programs involved in some studies, such as duration and intensity of the intervention program were varied. Besides, participants were diagnosed with traumatic brain injury or Attention Deficit Hyperactivity Disorder (ADHD), while in our study, healthy children only enrolled. Moreover, another study included in the meta-analysis showed limited statistical power because of a lack of randomization; even on the secondary outcome measures, some studies showed a positive, but not effective in the control group [34].

After participants finished the PA training or the MT program, the results revealed marked positive changes in many aspects: PA level, sleep quality, academic level, and addiction to electronic devices. The improvements in the quality of sleep, in the form of adequate duration and less interruption, were accompanied by positive attention function changes. These results concur with those of Falck et al. who found that sufficient sleep duration was correlated with good cognitive performance, independently of PA training [35].

The effects of PA and MT on children's attention was almost the same, with attention improving after both programs. Similar findings on a previous study reported that anaerobic exercise combined with gaming had significant positive impacts on young adults' attention and cognitive performance [36].

Additionally, in this study, positive relationships between age and attention in PA and MT programs matched the findings of Grammer et al. who examined age-related changes in error processing in young children and reported that older children showed faster and more accurate responses [37].

Concerning gender differences in cognitive control, our study concluded there was no association between gender and

attention improvements. These results concurred with those of Torpey et al. who reported no evidence of gender differences in error processing [37]. In contrast, Grammer et al. showed that girls made fewer mistakes and showed elevated processing of errors and correction amplitudes relative to boys. However, there were an equal number of boys and girls in that study; the greater number of boys in this study might be because boys' parents were more interested in enrolling their children because of perceived Executive Functioning (EF) deficits in male children compared to females.

Conclusion

The current study companied Physical Activity (PA) with Mental Training (MT) that had beneficial effects on school-age children's attention levels. Engaging in physical activity was noticed to improve attention level, sleep quality, academic level, and addiction to electronic devices after the intervention program.

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References

1. Arafat M. Exercises and tests to develop your child's intelligence. Iqra Foundation for Publishing and Distribution 2010.
2. Arundell L, Fletcher E, Salmon J, et al. A systematic review of the prevalence of sedentary behavior during the after-school period among children aged 5-18 years. Int J Behav Nutr Phys Act 2016; 13: 93.
3. Byun K, Hyodo K, Suwabe K, et al. Positive effect of acute mild exercise on executive function *via* arousal-related prefrontal activations: An fNIRS study. Neuroimage 2014; 98: 336-45.
4. Carson V, Hunter S, Kuzik N, et al. Systematic review of physical activity and cognitive development in early childhood. J Sci Med Sport 2016; 19(7): 573-8.
5. Chang YK, Chu CH, Wang CC, et al. Effect of acute exercise and cardiovascular fitness on cognitive function: an event-related cortical desynchronization study. Psychophysiology 2015; 52(3): 342-51.
6. Greeff JW, Bosker RJ, Oosterlaan J, et al. Effects of physical activity on executive functions, attention and academic performance in preadolescent children: A meta-analysis. J Sci Med Sport 2018; 21(5): 501-507.
7. Donnelly JE, Hillman CH, Castelli D, et al. Physical activity, fitness, cognitive function, and academic achievement in children: A systematic review. Med Sci Sports Exerc 2016; 48(6): 1197-222.
8. Douris PC, Handrakis JP, Apergis D, et al. The effects of aerobic exercise and gaming on cognitive performance. J Hum Kinet 2018; 61: 73-83.
9. Eriksen B, Eriksen C. Effects of noise letters upon the identification of a target letter in a nonsearch task. Perception and Psychophysics 1974; 16: 143-9.
10. Falck RS, Best JR, Davis JC, et al. Sleep and cognitive function in chronic stroke: a comparative cross-sectional study. Sleep 2019; 42(5): zsz040.
11. Falck RS, Best JR, Davis JC, et al. The independent associations of physical activity and sleep with cognitive function in older adults. J Alzheimers Dis 2018; 63(4): 1469-1484.
12. Fedewa A, Cornelius C, Ahn S. The use of bicycle workstations to increase physical activity in secondary classrooms. Health Psychology Report 2018; 6(1): 60-74.
13. Giles GE, Brunye TT, Eddy MD, et al. Acute exercise increases oxygenated and deoxygenated hemoglobin in the prefrontal cortex. Neuroreport 2014; 25(16): 1320-1325.
14. Grammer JK, Carrasco M, Gehring WJ, et al. Age-related changes in error processing in young children: A school-based investigation. Dev Cogn Neurosci 2014; 9: 93-105.
15. Hillman CH, Pontifex MB, Castelli DM, et al. Effects of the FITKids randomized controlled trial on executive control and brain function. Pediatrics 2014; 134(4): e1063-1071.
16. Jiang H, Johnstone SJ, Sun L, et al. Effect of neurocognitive training for children with adhd at improving academic engagement in two learning settings. J Atten Disord 2018; 25(3): 414-31.
17. Karch D, Albers L, Renner G, et al. The efficacy of cognitive training programs in children and adolescents: a meta-analysis. Dtsch Arztebl Int 2013; 110(39): 643-52.
18. Kvalø SE, Dyrstad SM, Bru E, et al. Relationship between aerobic fitness and academic performance: the mediational role of executive function. J Sports Med Phys Fitness 2019; 59(8): 1397-404.
19. Lambrick D, Stoner L, Grigg R, et al. Effects of continuous and intermittent exercise on executive function in children aged 8-10 years. Psychophysiology 2016; 53(9): 1335-42.
20. Lazarov O, Mattson MP, Peterson DA, et al. When neurogenesis encounters aging and disease. Trends Neurosci 2010; 33(12): 569-79.
21. Li BY, Tang HD, Qiao Y, et al. Mental training for cognitive improvement in elderly people: what have we learned from clinical and neurophysiologic studies? Curr Alzheimer Res 2015; 12(6): 543-52.
22. Lojovich JM. The relationship between aerobic exercise and cognition: Is movement medicinal? J Head Trauma Rehabil 2010; 25(3): 184-192.

23. Lutz A, Slagter HA, Rawlings NB, et al. Mental training enhances attentional stability: Neural and behavioral evidence. J Neurosci 2009; 29(42): 13418-13427.
24. Ma ZR, Shi LJ, Deng MH. Efficacy of cognitive behavioral therapy in children and adolescents with insomnia: A systematic review and meta-analysis. Braz J Med Biol Res 2018; 51(6): e7070.
25. McSween MP, Coombes JS, MacKay CP, et al. The immediate effects of acute aerobic exercise on cognition in healthy older adults: A systematic review. Sports Med 2019; 49(1): 67-82.
26. Mekari S, Fraser S, Bosquet L, et al. The relationship between exercise intensity, cerebral oxygenation and cognitive performance in young adults. Eur J Appl Physiol 2015; 115(10): 2189-2197.
27. Moscovich I, Stewart I. The big book of brain games. Workman Publishing Company, 2006.
28. Ogoh S, Tsukamoto H, Hirasawa A, et al. The effect of changes in cerebral blood flow on cognitive function during exercise. Physiol Rep 2014; 2(9): e12163
29. Pallavicini F, Ferrari A, Mantovani F. Video games for well-being: a systematic review on the application of computer games for cognitive and emotional training in the adult population. Front Psychol 2018; 9: 2127.
30. Parks EL, Madden DJ. Brain connectivity and visual attention. Brain Connect 2013; 3(4): 317-38.
31. Sigman A. Time for a view on screen time. Arch Dis Child 2012; 97(11): 935-42.
32. Smith PJ, Blumenthal JA, Hoffman BM, et al. Aerobic exercise and neurocognitive performance: a meta-analytic review of randomized controlled trials. Psychosom Med 2010; 72(3): 239-52.
33. Torpey DC, Hajcak G, Kim J, et al. Electrocortical and behavioral measures of response monitoring in young children during a Go/No-Go task. Dev Psychobiol 2012; 54(2): 139-150.
34. Tremblay MS, LeBlanc AG, Kho ME, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth. Int J Behav Nutr Phys Act 2011; 8: 98.
35. Fels IM, Wierike SC, Hartman E, et al. The relationship between motor skills and cognitive skills in 4-16 year old typically developing children: A systematic review. J Sci Med Sport 2015; 18(6): 697-703.
36. Verburgh L, Konigs M, Scherder EJ, et al. Physical exercise and executive functions in preadolescent children, adolescents and young adults: a meta-analysis. Br J Sports Med 2014; 48(12): 973-9.
37. Weng TB, Pierce GL, Darling WG, et al. Differential effects of acute exercise on distinct aspects of executive function. Med Sci Sports Exerc 2015; 47(7): 1460-1469.

*Correspondence to:

Afnan Alkhateeb

Department of Physical Therapy

College of Applied Medical Sciences

King Abdulaziz University

Jeddah, Kingdom of Saudi Arabia

E-mail: amalkhateeb@kau.edu.sa