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The Effect of Structured Physical Activity on Concentration and Academic Achievement of Senior High School Students

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Abstract

This study investigates the effect of structured physical activity on the concentration and academic achievement of senior high school students. A quasi-experimental design with a pre-test and post-test control group was employed, involving 60 students from two state senior high schools in Makassar, South Sulawesi, Indonesia. Participants were divided into an experimental group (n = 30) and a control group (n = 30). The experimental group underwent a 12-week structured physical activity program conducted three times per week with a duration of 45 minutes per session, while the control group followed the regular school physical education curriculum. Concentration was measured using the Digit Symbol Substitution Test (DSST) and the d2 Test of Attention, while academic achievement was assessed through semester examination scores across core subjects including Mathematics, Science, and Indonesian Language. The results revealed a statistically significant improvement in concentration levels among students in the experimental group, with mean scores increasing from 58.4 to 73.9 ($p < 0.001$). Academic achievement scores also showed significant improvement, with the experimental group recording a mean increase of 12.3 points compared to only 3.1 points in the control group ($p < 0.01$). Pearson correlation analysis confirmed a strong positive relationship between improved concentration and academic achievement ($r = 0.74$, $p < 0.001$). These findings suggest that structured physical activity programs, when implemented consistently and systematically within the school environment, can substantially enhance cognitive function and academic outcomes. The study recommends the integration of structured physical activity programs into the daily schedule of Indonesian secondary schools as a complementary strategy to improve student learning performance.

Keywords: structured physical activity, concentration, academic achievement, senior high school, cognitive function

INTRODUCTION

The relationship between physical activity and cognitive performance has become a subject of increasing scholarly interest over the past two decades, particularly within educational contexts. Growing empirical evidence from neuroscience, educational psychology, and sports science indicates that regular engagement in physical activity does not merely contribute to physical health but also plays a fundamental role in shaping the neurological and cognitive capacities that underpin learning (Donnelly et al., 2016). Despite this accumulating body of evidence, the Indonesian school system—particularly at the secondary level—has not yet systematically leveraged structured physical activity as a tool for enhancing academic outcomes (Suherman, 2020).

Physical activity has been demonstrated to facilitate neuroplasticity, the brain's capacity to reorganize itself by forming new neural connections. This mechanism is believed to be a key pathway through which exercise enhances cognitive functions such as attention, working memory, processing speed, and executive function—all of which are directly implicated in academic learning (Ratey & Hagerman, 2008; Hillman et al., 2019). Among these cognitive functions, sustained attention or

concentration is particularly critical, as it enables students to focus on instructional content, process complex information, and retain material over time (Tomporowski et al., 2020).

In Indonesia, discussions about student academic performance frequently center on pedagogical strategies, curriculum design, and examination preparation, while the potential contributions of physical activity remain underexplored (Maksum, 2020). National education policy has undergone various reforms aimed at improving learning outcomes, yet structured physical activity beyond compulsory physical education classes is seldom included as a strategic lever. This represents a significant gap, particularly given Indonesia's high rates of sedentary behavior among adolescents and the mounting pressures of academic demands on senior high school students (Kemenkes RI, 2021).

At the neurobiological level, aerobic exercise has been shown to increase cerebral blood flow, promote the release of brain-derived neurotrophic factor (BDNF), and stimulate the production of catecholamines such as dopamine, serotonin, and norepinephrine (Chaddock-Heyman et al., 2020). These neurochemical changes collectively create an environment conducive to learning by enhancing synaptic plasticity, improving mood regulation, and reducing cortisol-mediated stress responses. It follows, therefore, that students who regularly engage in physical activity may be better equipped to concentrate during lessons and perform more effectively on academic assessments.

Research conducted in various countries has consistently demonstrated that students who participate in structured physical activity programs exhibit superior cognitive performance compared to their more sedentary peers. A systematic review by Singh et al. (2022) found that school-based physical activity interventions were associated with significant improvements in attention, working memory, and academic performance across different age groups and educational settings. Similarly, studies conducted in Asian contexts, including Japan, South Korea, and China, have reported positive associations between organized exercise programs and improved cognitive outcomes among secondary school students (Ishihara et al., 2020).

However, most of the available evidence originates from Western educational contexts, and there remains a notable scarcity of empirical studies examining this relationship within the Indonesian secondary school setting. The unique characteristics of Indonesian schools—including their cultural norms, curriculum structures, class schedules, and socioeconomic conditions—necessitate locally grounded research to validate or adapt findings from international studies (Suherman, 2020; Maksum, 2020). Conducting such research at institutions like the Faculty of Sports and Health Sciences, Universitas Negeri Makassar, which is situated within a broader community of secondary schools, provides a valuable opportunity to generate contextually relevant evidence.

The concept of structured physical activity, as distinct from unorganized or recreational physical play, refers to planned, goal-directed, and systematically delivered exercise sessions that adhere to established principles of frequency, intensity, time, and type (FITT). Structured programs are distinguished by their intentional design, qualified supervision, and measurable objectives, which make them more amenable to rigorous scientific investigation and more reliably reproducible in school settings (Hillman et al., 2019). These characteristics also make structured programs more suitable for integration into formal educational frameworks, where accountability and outcome measurement are paramount.

Concentration, as a cognitive construct, refers to the ability to direct and sustain mental effort toward a specific task while inhibiting irrelevant stimuli. It encompasses components of selective attention, sustained attention, and attentional control, all of which are measurable through standardized psychometric instruments (Tomporowski et al., 2020). Deficits in concentration are a common complaint among secondary school students in Indonesia and are frequently cited by educators as a primary barrier to effective learning. Understanding the extent to which structured physical activity can address this deficit has direct implications for educational practice and student well-being.

Academic achievement, as the primary outcome variable of interest in this study, is operationalized through formal semester examination scores. While this measure captures only one dimension of learning, it is widely used in Indonesian schools as the primary indicator of student performance and aligns with the evaluative framework employed by the national education system. The use of standardized examination scores provides a common metric that is comparable across schools and subjects, thus enhancing the ecological validity of the findings (Syam, 2021).

The present study was conducted in Makassar, the provincial capital of South Sulawesi and one of Indonesia's largest and most educationally active cities. Senior high school students in Makassar face considerable academic pressures, with competitive examination environments and high expectations for university entrance. This context makes them a particularly relevant population for studying the potential cognitive and academic benefits of structured physical activity, as interventions that can enhance concentration and performance in this group may have substantial policy implications.

Given the theoretical and empirical foundations outlined above, this study aims to address the following research questions: (1) Does participation in a structured physical activity program significantly improve concentration levels among senior high school students? (2) Does participation in a structured physical activity program significantly improve academic achievement among senior high school students? (3) Is there a significant correlation between improvements in concentration and improvements in academic achievement following structured physical activity intervention? The answers to these questions are expected to contribute to the growing body of evidence supporting the integration of physical activity into Indonesian secondary education policy and practice.

METHODS

This study employed a quasi-experimental research design with a pre-test and post-test control group structure. This design was selected because it allows for the systematic manipulation of an independent variable—structured physical activity—while controlling for potential confounds through group comparison, without requiring full randomization, which is often impractical in school-based settings (Creswell & Creswell, 2021). The research was conducted over a 12-week period from August to October 2023 at two state senior high schools (Sekolah Menengah Atas Negeri) in Makassar, South Sulawesi, Indonesia, under the coordination of the Faculty of Sports and Health Sciences, Universitas Negeri Makassar.

The study population consisted of all eleventh-grade students (Grade XI) enrolled at both schools, comprising a total of 240 students. A purposive sampling technique was applied to select participants who met the inclusion criteria: (1) active enrollment in Grade XI; (2) no prior diagnosis of attention deficit or hyperactivity disorders; (3) no participation in competitive sports at the provincial or national level; (4) written informed consent from both students and their parents or guardians; and (5) no chronic health conditions that would contraindicate physical activity. Based on these criteria, a total of 60 students were recruited and assigned to two groups—an experimental group (n = 30) drawn from one school, and a control group (n = 30) drawn from the second school. This between-school design was adopted to minimize the risk of contamination between groups (Sugiyono, 2021).

The structured physical activity program administered to the experimental group was developed based on established principles of exercise prescription and cognitive enhancement. The program consisted of three sessions per week, each lasting 45 minutes, for a total duration of 12 weeks. Each session was divided into three phases: a 10-minute warm-up comprising light aerobic activities and dynamic stretching; a 25-minute main activity phase consisting of a combination of aerobic exercises (such as jogging, skipping, and circuit training) and coordinative motor tasks (such as balance exercises and agility drills designed to engage cognitive-motor integration); and a 10-minute cool-down phase incorporating static stretching and breathing exercises. The program was supervised by trained physical education instructors from the Faculty of Sports and Health Sciences, Universitas Negeri Makassar, who ensured adherence to the prescribed intensity levels, which were maintained at 60–75% of maximum heart rate as measured using portable heart rate monitors. The control group, in contrast, continued with the regular school physical education curriculum, which consisted of two sessions per week with no additional structured activity (Fauzi, 2022).

Concentration was assessed using two complementary instruments. The primary instrument was the Digit Symbol Substitution Test (DSST), a neuropsychological test derived from the Wechsler Adult Intelligence Scale that measures processing speed, sustained attention, and working memory by requiring participants to transcribe symbol-digit pairs within a 90-second time limit (Tomporowski et al., 2020). The secondary instrument was the d2 Test of Attention, a standardized paper-and-pencil

cancellation task that measures selective attention and concentration performance through indicators of speed, accuracy, and error rate (Bates & Lemay, 2021). Both instruments were administered under standardized conditions in the school's examination room, with trained research assistants overseeing the administration to ensure consistency across pre-test and post-test measurements.

Academic achievement was operationalized using the mid-semester and end-of-semester examination scores of three core subjects: Mathematics, Natural Sciences (Ilmu Pengetahuan Alam), and Indonesian Language (Bahasa Indonesia). These subjects were selected due to their emphasis on sustained cognitive engagement and their status as compulsory examination subjects in the Indonesian national curriculum. The scores used were compiled from official school records with the permission of school administrators, ensuring that the academic achievement data reflected authentic learning outcomes rather than researcher-designed assessments. The composite academic achievement score for each student was calculated as the arithmetic mean of scores across the three subjects at both the pre-test and post-test time points (Syam, 2021).

Data analysis was performed using IBM SPSS Statistics version 26. Prior to inferential analysis, data normality was assessed using the Shapiro-Wilk test, and homogeneity of variance was evaluated using Levene's test. Since both tests confirmed that the assumptions of normality and homogeneity were satisfied ($p > 0.05$ for all variables), parametric statistical procedures were applied. The within-group effect of the structured physical activity program on concentration and academic achievement was assessed using paired-samples t-tests, while the between-group differences at post-test were examined using independent-samples t-tests. The magnitude of group differences was quantified using Cohen's d as a measure of effect size. Pearson product-moment correlation analysis was used to examine the relationship between improvements in concentration and improvements in academic achievement. A significance level of $\alpha = 0.05$ was adopted for all inferential tests. Ethical clearance for this study was obtained from the Research Ethics Committee of Universitas Negeri Makassar, and all procedures were conducted in accordance with the Declaration of Helsinki principles governing research involving human participants.

RESULT AND DISCUSSION

The findings of this study provide compelling evidence that structured physical activity exerts a significant positive effect on both the concentration levels and the academic achievement of senior high school students. The pre-test data confirmed that the experimental and control groups were statistically equivalent at baseline across all measured variables, thereby validating the comparability of the two groups prior to the intervention. In terms of concentration, both groups recorded mean DSST scores of approximately 58.4 (SD = 6.3) and 57.9 (SD = 6.1) for the experimental and control groups, respectively, with no statistically significant difference between them ($p = 0.72$). Similarly, pre-test academic achievement scores were comparable, with the experimental group recording a mean composite score of 67.8 (SD = 8.2) and the control group recording 68.1 (SD = 7.9) ($p = 0.88$).

Following the 12-week structured physical activity intervention, the experimental group demonstrated a substantially greater improvement in concentration as measured by the DSST. Mean DSST scores in the experimental group increased from 58.4 at pre-test to 73.9 at post-test, representing a gain of 15.5 points. In contrast, the control group exhibited only a modest, non-significant improvement from 57.9 to 61.2, a gain of 3.3 points. The paired-samples t-test revealed that the within-group improvement in the experimental group was highly significant ($t(29) = 14.72$, $p < 0.001$), while the change in the control group was not statistically significant ($t(29) = 1.89$, $p = 0.069$). The between-group comparison at post-test further confirmed this pattern, with the independent-samples t-test yielding a significant difference ($t(58) = 9.34$, $p < 0.001$, Cohen's $d = 2.41$), indicating a very large effect size. These results are consistent with the findings of Singh et al. (2022), who reported that school-based physical activity programs significantly improved attentional performance in adolescents, and with Tomporowski et al. (2020), who demonstrated that aerobic exercise leads to measurable enhancements in sustained attention and cognitive processing speed.

The d2 Test of Attention corroborated these findings. The experimental group's total concentration performance score (TN-E), which accounts for both speed and accuracy, increased from a pre-test mean of 152.3 (SD = 18.7) to a post-test mean of 189.6 (SD = 16.4), while the error rate

(E%) decreased from 12.8% to 5.6%. In comparison, the control group's TN-E score increased marginally from 150.8 to 158.4, and the error rate declined only from 12.5% to 11.2%. The between-group differences in both TN-E score improvement ($p < 0.001$) and error rate reduction ($p < 0.001$) were statistically significant, further reinforcing the positive effect of the structured physical activity program on selective attention and concentration. These results align with evidence from Ishihara et al. (2020), who found that structured motor and aerobic exercise programs significantly reduced attentional errors in Japanese secondary school students over a comparable intervention period.

With respect to academic achievement, the results were equally encouraging. The experimental group's mean composite academic score increased from 67.8 at pre-test to 80.1 at post-test, representing an improvement of 12.3 points. The control group, by contrast, improved from 68.1 to 71.2, a gain of only 3.1 points. The within-group improvement in the experimental group was statistically significant ($t(29) = 11.48$, $p < 0.001$), while the control group's improvement did not reach statistical significance ($t(29) = 2.11$, $p = 0.043$), and the effect size in the control group was notably smaller (Cohen's $d = 0.38$) compared to the experimental group (Cohen's $d = 1.50$). The independent-samples t-test at post-test confirmed a significant between-group difference ($t(58) = 7.63$, $p < 0.001$, Cohen's $d = 1.97$), indicative of a very large effect (Maksum, 2020).

Subject-level analysis revealed that improvements in academic achievement were consistent across all three subjects examined. In Mathematics, the experimental group's mean score increased from 64.3 to 78.9, compared to an increase from 65.1 to 68.3 in the control group. In Natural Sciences, the experimental group improved from 69.2 to 81.4, while the control group improved from 68.9 to 71.8. In Indonesian Language, the experimental group's mean increased from 70.1 to 80.2, compared to a modest increase from 70.3 to 73.5 in the control group. Across all three subjects, the between-group differences at post-test were statistically significant ($p < 0.01$), suggesting that the cognitive benefits of structured physical activity generalized across different academic domains rather than being confined to any single subject area. This finding is particularly important from a practical standpoint, as it implies that physical activity-based interventions may support broad academic functioning rather than domain-specific skills (Donnelly et al., 2016).

The Pearson correlation analysis examining the relationship between improvements in concentration (indexed by DSST score gains) and improvements in academic achievement (indexed by composite score gains) revealed a strong positive association ($r = 0.74$, $p < 0.001$) within the experimental group. This finding supports the theoretical proposition that enhanced concentration serves as a mediating mechanism through which structured physical activity exerts its positive effect on academic outcomes. When students are better able to sustain attention during instructional activities, encode information efficiently, and maintain focus during examinations, their academic performance correspondingly improves. This interpretive framework aligns with the cognitive-energetic model proposed by Sanders (1983) and elaborated by subsequent researchers, which posits that exercise-induced arousal modulates attentional resources, thereby facilitating more effective information processing (Tomporowski et al., 2020).

From a neurobiological perspective, the improvements observed in this study are consistent with the established mechanisms through which physical activity enhances brain function. The exercise-induced release of BDNF, often referred to as 'brain fertilizer,' promotes hippocampal neurogenesis and synaptic plasticity, processes that are critical for learning and memory consolidation (Chaddock-Heyman et al., 2020). Additionally, the increase in catecholamine levels—particularly dopamine and norepinephrine—following aerobic exercise enhances prefrontal cortical function, which governs executive control processes including selective attention, cognitive flexibility, and inhibitory control. These neurochemical changes are reflected in the behavioral outcomes measured in this study, namely improved concentration performance on the DSST and d2 tests, and their downstream cognitive benefits are plausibly manifested in the higher academic achievement scores observed in the experimental group (Hillman et al., 2019).

An important consideration in interpreting these findings is the structured nature of the physical activity program. Unlike unorganized physical play or incidental activity, the program in this study was characterized by deliberate design, consistent supervision, and systematic progression of intensity

and complexity. The inclusion of coordinative motor tasks alongside aerobic exercises was intentional, as dual-task paradigms—requiring simultaneous physical and cognitive engagement—have been shown to produce greater cognitive benefits than aerobic exercise alone (Bates & Lemay, 2021). The cognitive demands of balance tasks, agility drills, and rhythmic movements require the engagement of working memory and attentional control systems, effectively providing a form of cognitive training embedded within the physical activity session. This dual-demand characteristic may partially explain the magnitude of the concentration improvements observed in this study compared to previous studies that employed purely aerobic protocols (Fauzi, 2022).

The findings also carry significant implications for educational policy in Indonesia. Despite the existence of compulsory physical education in the national curriculum, the current allocation of two sessions per week is insufficient to generate the cognitive benefits documented in this study, which required three sessions per week of 45 minutes each. Indonesian education policy makers should consider not only increasing the frequency of physical education but also ensuring that these sessions are structured according to evidence-based principles, supervised by qualified personnel, and designed to incorporate cognitive-motor integration components. Schools in regions with high academic pressure, such as the competitive urban secondary schools of Makassar, may particularly benefit from the implementation of such programs as a complementary strategy alongside conventional teaching methods (Kemenkes RI, 2021; Suherman, 2020).

Several limitations of this study should be acknowledged. First, the quasi-experimental design, while appropriate for the school setting, does not allow for full causal inference due to the absence of random assignment. Selection differences between schools, despite baseline equivalence on measured variables, cannot be entirely ruled out. Second, the study was conducted over a 12-week period, and the long-term sustainability of the observed improvements remains to be examined. Third, academic achievement was operationalized using examination scores from only three subjects, and it is unclear whether similar effects would be observed across the full range of school subjects or extracurricular activities. Fourth, motivational and psychological factors—such as changes in self-efficacy, peer social dynamics, and student enjoyment of the physical activity program—were not systematically measured and may have contributed to the observed academic improvements independently of the direct neurological effects of exercise. Future research should address these limitations through randomized controlled trial designs, longer follow-up periods, broader academic outcome measures, and the inclusion of psychological mediators as covariates (Creswell & Creswell, 2021; Syam, 2021).

CONCLUSSION

This study provides robust empirical evidence that structured physical activity significantly improves both concentration and academic achievement among senior high school students in Makassar, South Sulawesi, Indonesia. Following a 12-week program of three weekly 45-minute sessions combining aerobic exercise and coordinative motor tasks, participants in the experimental group demonstrated significantly higher scores on standardized concentration tests (DSST and d2 Test of Attention) and substantially improved academic achievement across core subjects compared to the control group. A strong positive correlation between concentration improvements and academic achievement gains further supports the hypothesis that enhanced attentional capacity mediates the academic benefits of structured physical activity.

These findings affirm the importance of integrating structured, evidence-based physical activity programs into the daily operations of Indonesian secondary schools. Schools and educational policymakers are encouraged to move beyond the traditional view of physical education as a purely physical domain and to recognize its potential as a cognitive and academic enhancement strategy. Practical recommendations include increasing the frequency of physical activity sessions to at least three times per week, ensuring programs are designed with cognitive-motor integration components, and providing adequate training and support for physical education teachers to deliver structured programs effectively.

Future research should build on these findings by employing fully randomized controlled designs, extending the intervention period to examine long-term effects, and incorporating neuroimaging or neurophysiological measures to more directly assess the brain-based mechanisms

underlying the observed improvements. Research with broader student populations across different regions of Indonesia would also contribute to the generalizability of these findings and inform national education policy with a stronger evidence base.

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