

## Optimizing Short-Term Memory in 12-Year-Olds: A Combined Intervention of Dual-Task Training and Aerobic Exercise

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### Abstract

*Background: Short-term memory disorders can have an impact on a child's future. Purpose: This study aims to determine the effect of a combination of Dual Task Training and Aerobic Exercise on improving short-term memory in 12-year-old children. Method: This research used a quasi-experimental research design with a pre-test and post-test two group design. Carried out for 4 weeks with a frequency of 3 times a week. The research subjects consisted of 28 people, 14 people in the Intervention I group, a combination of Dual Task Training and Aerobic Exercise, and 14 people in the Intervention II Aerobic Exercise group. And measurements were carried out using the Digit Span Test and Harvard Test. Results: Test showed a  $p < 0.001$  in the Combination Intervention of Dual Task Training and Aerobic Exercise, and a  $p < 0.001$  in the Intervention II Aerobic Exercise group. The test of difference of 2 mean is  $p = 0.01$ , which means there is a significant difference between the two interventions with the average difference between intervention group I being 2.79 and intervention II being 1.71. Conclusion: This research can be concluded that the combination of Dual Task Training and Aerobic Exercise intervention is more influential in improving the short-term memory of children aged 12 years.*

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## INTRODUCTION

Short-term memory disorders can have an impact on a child's future (1). Memory disorders can affect a child's academic performance because children experience learning difficulties due to challenges in understanding and following instructions from teachers; the ability to recall what has been seen or heard, or even new experiences, will have a significant influence on the learning process (2).

Memory is a part of an individual's cognitive component that is highly useful in storing various types of information. Short-term memory is a core element of cognitive development, essential for storing and applying information in daily learning processes (3). While previous studies have established the independent benefits of dual-task training in facilitation guided neuroplasticity and aerobic exercise in improving working memory function through increased prefrontal cortex activity, there remains a significant research gap regarding their combined efficacy. The synergistic potential of simultaneous motor-cognitive loading alongside aerobic cardiovascular stimulation is hypothesized to yield a more holistic neurophysiological enhancement compared to single-modality interventions (4). Short-term memory has a limited capacity and a relatively very short retention span, specifically retaining information for only 15-30 seconds, which will be lost if not repeated (5). Therefore, specific strategies are needed to store information for a longer duration.

Consequently, training and improving short-term memory performance are highly necessary to refresh stored memories. Training and improving short-term memory performance can be achieved through the role of physiotherapy (3,6). The role of physiotherapy in improving children's short-term memory is preventive, aiming to prevent the decline of the system and functional performance of the child's brain. This prevention can be carried out through physiotherapy interventions in the form of dual-task training and aerobic exercise. Dual-task training can be defined as an exercise method that involves performing two tasks or activities with different objectives simultaneously. Performing dual-task training requires an individual's ability to focus their attention and concentrate more when receiving information, as well as handling multiple stimuli simultaneously (7). Meanwhile, aerobic exercise is a type of exercise that utilizes a sufficient amount of oxygen and involves rhythmic, continuous movements of large muscle groups. The combination of these two exercises can increase neural activity in the prefrontal cortex caused by an increase in hemoglobin during its execution (8).

Dual-task training facilitates guided plasticity that can contribute to cognitive improvement (9). Motor training facilitates neuroplasticity, and cognitive training guides neuroplasticity. Previous studies have found the effect of dual-task training on short-term memory in children, and other conducted studies indicate an improvement in the short-term memory of school children after being given aerobic exercise. Previous studies indicate that the intensity of aerobic exercise strongly affects memory improvement; this study showed that moderate-intensity aerobic exercise can improve working memory in children (10,11).

This combined approach holds substantial practical relevance in intensive educational settings. For instance, at Pondok Pesantren Miftahul Jannah Kranggan, an Islamic boarding school in Bekasi, 12-year-old students undergo rigorous academic activities such as memorizing Arabic vocabulary. Addressing memory retention challenges in such practical environments requires an optimal exercise dosage and strategy. Thus, this study aims to determine the effect of a combined intervention of dual-task training and aerobic exercise on the short-term memory capabilities of 12-year-old children in a functional educational setting.

## **METHODS**

This study employed a quasi-experimental design with a two-group pre-post test. The samples were selected using purposive sampling, acknowledging the potential for selection bias inherent in non-randomized designs. A total of 28 individuals were selected based on specific inclusion criteria: healthy 12-year-old students currently enrolled in the boarding school without any physical or neurological conditions that would impede physical exercise. The research was conducted from February to March at Pondok Pesantren Miftahul Jannah Kranggan.

The measurement instruments for data collection were the Digit Span Test to assess the children's short-term memory before and after the intervention, and the Harvard Step Test to assess the children's fitness level. The study began with an interview, followed by the Digit Span Test and the Harvard Step Test, both administered prior to the intervention. Dual-task training and aerobic exercise were administered 3 times a week for 4 weeks.

Dual-task training with a simultaneous motor-cognitive training technique was performed using 4 types of exercises: walking straight back and forth combined with counting; walking zig-zag back and forth combined with naming friends, fruits, or animals; walking sideways diagonally back and forth combined with answering arithmetic problems; and walking straight with weights back and forth combined with answering arithmetic problems. Aerobic exercise was provided through jogging for 20 minutes, preceded by a 5-minute warm-up and followed by a 5-minute cool-down.

The evaluation of short-term memory measurements was conducted after 4 weeks of intervention. This study obtained ethical approval from the ethics committee of Universitas Negeri Semarang on January 29, 2024, under number 038/KEPK/FK/KLE/2024.

## RESULTS AND DISCUSSION

This study involved 28 respondents, evenly distributed between Group I and Group II, with each group consisting of 14 children. The subjects of this study had a gender distribution of 14 individuals per intervention group, with 8 females and 6 males.

**Table 1.** Respondent Demographic (n=28)

Variable	Group I			Group II		
	Frequency (n)	%	Mean±SD	Frequency (n)	%	Mean±SD
Girls	8	57.1		8	57.1	
Boys	6	42.9		6	42.9	
Mean Fitness of Girls (Pre)			41.04±7.35			39.69±6.25
Mean Fitness of Girls (Post)			61.32±5.93			64.19±5.04
Mean Fitness of Boys (Pre)			36.76±5.65			41.29±6.49
Mean Fitness of Boys Post)			58.11±5.04			64.30±8.51
Mean Short-Term Memory of Children (Pre)			<b>8.36 ± 1.00</b>			<b>8.71 ± 1.26</b>
Mean Short-Term Memory of Children (Post)			<b>11.14 ± 1.09</b>			<b>10.50 ± 1.22</b>
<b>Total</b>	<b>14</b>	<b>100</b>		<b>14</b>	<b>100</b>	

Based on gender demographics, both groups exhibited highly identical and homogeneous proportions. Female respondents dominated the course of the study in both groups with a percentage of 57.1% (8 children), while male respondents accounted for 42.9% (6 children). This equivalence in initial distribution minimizes potential research bias originating from innate physiological capacity differences related to gender.

Descriptively, the initial measurement (pre-test) assessed physical fitness and short-term memory, serving as the baseline before the intervention. In the physical fitness variable, female children in Group I and Group II commenced the study with relatively equivalent mean values, specifically 41.04±7.35 and 39.69±6.25, respectively. A similar condition was observed in male children, with the initial mean fitness of Group I at 36.76±5.65 and Group II at 41.29±6.49. Meanwhile, for the primary variable of short-term memory capability, both groups also started from a balanced baseline, with a mean of 8.36±1.00 in Group I and 8.71±1.26 in Group II.

After the intervention was completed (post-test), descriptive analysis indicated a positive and measurable improvement trend across all variables in both groups. There was a substantial increase in the mean values of physical fitness; the fitness of female children in Group I surged to 61.32±5.93 and Group II to 64.19±5.04. A parallel improvement was also observed in male children, with the mean fitness of Group I rising to 58.11±5.04 and Group II reaching 64.30±8.51. In line with these physical fitness improvements, the children's short-term memory also increased. Group I recorded an increase in the mean memory score to 11.14±1.09, and Group II increased to 10.50±1.22.

**Table 2.** Short-Term Memory Categories

Category	Score	Group I				Group II			
		Pre		Post		Pre		Post	
		f	%	f	%	f	%	f	%
<b>Very Low</b>	0-4	0	0	0	0	0	0	0	0
<b>Low</b>	5-8	8	57.1	0	0	7	50	1	7.1
<b>Less than Sufficient</b>	9	4	28.6	1	7.1	4	28.6	1	7.1
<b>Sufficient</b>	10-11	2	14.3	7	50	3	21.4	10	71.4
<b>More than Sufficient</b>	12	0	0	5	35.7	0	0	1	7.1
<b>High</b>	13-16	0	0	1	7.1	0	0	1	7.1
<b>Very High</b>	>17	0	0	0	0	0	0	0	0
<b>Total</b>		<b>14</b>	<b>100</b>	<b>14</b>	<b>100</b>	<b>14</b>	<b>100</b>	<b>14</b>	<b>100</b>

The frequency distribution and percentages of children's short-term memory capabilities before (pre-test) and after (post-test) the intervention are presented in Table 2. In the initial measurement (baseline), the short-term memory profiles of respondents in both groups showed similar, suboptimal tendencies. The majority of respondents in Intervention Group I (57.1%) and Intervention Group II (50%) dominated the 'Low' memory category. Furthermore, the proportion of respondents in the 'Less than Sufficient' category was quite similar in both groups, at 28.6%. This equivalent initial condition provides an ideal foundation for comparing the effectiveness of the two intervention types.

After completing the four-week training program, a marked improvement in the memory profile was observed in both treatment groups. In Intervention Group I (combination of Dual Task Training and Aerobic Exercise), the intervention successfully eliminated all respondents from the 'Low' category (0%). A substantial surge in distribution occurred, with 50% of respondents moving up to the 'Sufficient' category and 35.7% entering the 'More than Sufficient' category. Furthermore, there was a representation of respondents (7.1%) who achieved the 'High' memory category.

An upward trend was also observed in Intervention Group II (Aerobic Exercise only), albeit with a slightly different pattern of outcome distribution. The absolute majority of respondents in this group (71.4%) clustered and improved into the 'Sufficient' category. Unlike Group I, which had a broader spread into the upper categories, only a small fraction of respondents in Group II reached the 'More than Sufficient' (7.1%) and 'High' (7.1%) categories. In comparison, 7.1% remained in the 'Low' category. Overall, these qualitative data confirm that physical stimulation positively impacts children's cognition. However, the combination of simultaneous motor and cognitive loading (Group I) facilitates a more evenly distributed improvement in short-term memory quality to higher levels than a single aerobic exercise.

**Table 3.** Comparison Test

Group	<i>p-value</i> (paired sample t-test)
I	0.000
II	0.000

To assess the effectiveness of each treatment on changes in children’s short-term memory before and after the intervention, hypothesis testing was conducted using the parametric Paired Sample T-Test, as presented in Table 3. The test results indicate that both Intervention Group I (Combination of Dual Task Training and Aerobic Exercise) and Intervention Group II (Aerobic Exercise only) yielded p-values < 0.001 (p < 0.05). This statistical fact confirms that both intervention designs have independently demonstrated the ability to meaningfully increase respondents’ short-term memory capacity.

**Tabel 4.** Difference Analysis

Group	Mean	SD	p-value
I	2.79	1.05	0.01
II	1.71	1.06	

Although both interventions proved effective, a more in-depth evaluation is required to identify which modality offers the greatest leverage. Table 4 outlines the results of the effectiveness difference test using the Independent Sample T-Test, which compares the mean difference (delta) in memory improvement between the two groups. The analysis results reveal that Intervention Group I recorded a mean difference increase of 2.79 (SD = 1.05). This figure indicates a significantly larger margin of the Intervention Group II, which recorded a mean difference of 1.71 (SD = 1.06). The comparison of these mean differences is validated by the difference test results, which yielded a p-value of 0.01 ( $p < 0.05$ ). Based on these parameters, it can be conclusively drawn that there is a significant difference in effect between the two interventions. Clinically, these data demonstrate that physical exercise loading (aerobic) integrated with cognitive challenges (dual task) produces far superior, holistic, and effective neurophysiological stimulation for optimizing a child's short-term memory compared to pure aerobic exercise.

**Discussion**

This study was conducted from February 2, 2024, to March 2, 2024, at Pondok Pesantren Miftahul Jannah Kranggan, Bekasi City. This study aims to determine the effect of a combined intervention of Dual Task training and Aerobic Exercise on the short-term memory of 12-year-old children. The subjects of this study had a gender distribution of 14 individuals per intervention group, with 8 females and 6 males. Prior to the study's implementation, the samples' short-term memory was assessed using the Digit Span Test, and their physical fitness was assessed using the Harvard Step Test. Subsequently, Intervention Group I received a combination of Dual-Task Training and Aerobic Exercise, while Intervention Group II received only Aerobic Exercise.

The results of the Paired Sample T-test conducted by the researcher showed a p-value of 0.000 for both interventions administered. In this case, a significance value  $<0.05$  indicates that the intervention had an effect in both Intervention Group I (combination of dual-task training and aerobic exercise) and Intervention Group II (aerobic exercise). This result corroborates previous research that found an effect of Dual-Task Training on short-term memory in children aged 10-11 years. That study showed a significant difference in children's short-term memory before and after 12 intervention sessions, with a significance value of  $p = 0.0001$  ( $p < 0.05$ ). This is supported by another study demonstrating an increase in short-term memory in schoolchildren after aerobic exercise.(9,12) The improvement in short-term memory in this study is evidenced by the intervention group's p-value of 0.001 ( $p < 0.05$ ).

Based on the results obtained from the independent sample t-test comparing the mean differences between the two groups—namely Intervention Group I (Combination of Dual Task Training and Aerobic Exercise) and Intervention Group II (Aerobic Exercise)—a p-value of 0.013 was obtained, which means there is a significant difference in the effect. The change value in short-term memory for Intervention Group I (Combination of Dual Task Training and Aerobic Exercise) was 2.79, while for Intervention Group II (Aerobic Exercise) it was 1.71. This difference is attributed to the combination of Dual Task Training and Aerobic Exercise in Intervention Group I, compared with Intervention Group II, which received only the Aerobic Exercise intervention. Additionally, genetic factors, differences in nutritional status, and varying stress levels among respondents may affect the outcome of these differences (13).

This study appears to be more significant compared to previous research. In this study, a combination of two interventions was utilized, whereas previous studies only employed a single intervention in the form of Dual Task Training or Aerobic Exercise alone (13). The p-value result in the previous study was found to be 0.0001,(14) whereas in this study the p-value is 0.000. However, this difference could be due to differences in respondents' age criteria, despite the same session duration. This also applies to the aerobic exercise intervention, which yielded a larger mean difference than the previous study (8). In the previous study, the mean difference in children's short-term memory after the Aerobic Exercise intervention was only 0.077, whereas in this study, the mean difference after the intervention is 2.79. This could be due to differences in age and the type of aerobic exercise administered, which may make it more effective than in previous research (9,14). In that study, there was no significant change in value in the treatment group given the aerobic exercise intervention in the form of chronic aerobic gymnastics.

Previous studies have shown that motor training can induce positive changes in brain structure, enhancing learning and motor performance by activating several brain regions, including the prefrontal cortex (11). This performance enhancement can be furthered through cognitive training. The combination of these two exercises can increase neural activity in the prefrontal cortex by increasing hemoglobin levels during their execution (10). Dual-task training facilitates guided plasticity that can contribute to cognitive enhancement. Motor training facilitates neuroplasticity, and cognitive training guides neuroplasticity (15). Dual Task Training induces neurogenesis through distinct yet complementary mechanisms: exercise stimulates precursor cell proliferation, while cognitive stimulation increases the survival of newborn cells. The synergistic effect of motor-cognitive tasks is based on neurotrophic factors (14). Meanwhile, aerobic exercise can regulate and elevate neurotrophic factors such as brain-derived neurotrophic factor (BDNF), which is associated with memory. BDNF can alter the expression and translocation of membrane receptors, stimulating and activating numerous pathways to alter synaptic plasticity and improve memory (16,17). Aerobic exercise affects the structure and function of the brain by altering molecules and cells, ultimately impacting memory (18).

Based on the conducted study, administering a combination of dual-task training and aerobic exercise can enhance short-term memory in children (16). This improvement in short-term memory is supported by enhanced physical fitness, which promotes increased blood flow, oxygenation, and blood capillary growth, as well as the production of neurotrophins that affect brain physiology, thereby facilitating memory processes (19,20). Furthermore, this exercise combination can elevate brain-derived neurotrophic factor (BDNF) levels, which function to stimulate synaptic plasticity and regulate synaptic strength (21). BDNF is found in relatively high concentrations in the hippocampus, amygdala, cerebellum, and cerebral cortex. The highest concentration is in the hippocampus, which plays a pivotal role in memory. BDNF can increase the number of receptors on the hippocampal plasma membrane, thereby enhancing receptor activity within the hippocampus (22,23). The combination of dual-task training and aerobic exercise leads to improved brain vascularization and affects the communication of the hypothalamic-pituitary axis to the limbic system (which is involved in memory), the amygdala (which is responsible for emotional regulation), and the hippocampus (which plays a role in memory, mood, and motivation) (24,25).

Clinically, the findings of this study suggest that physical therapy and physical education programs for adolescents should go beyond single physical routines. Integrating simultaneous cognitive challenges with moderate-intensity aerobic exercises can provide a superior, holistic neurophysiological stimulation, making it a highly recommended preventive and promotive strategy for optimizing a child's academic-related memory. Despite the positive findings, this study has

several limitations. The use of purposive sampling without true randomization may introduce selection bias, limiting the generalizability of the results. Furthermore, the study was conducted with a relatively small sample size (n=28) and over a short intervention duration of only 4 weeks. Future studies should employ randomized controlled trial (RCT) designs with larger sample sizes, longer intervention periods, and standardized measures of exercise intensity to validate these findings

## CONCLUSION

An improvement was observed, with the average short-term memory score increasing from an initial 8.36 to 11.14. Therefore, it can be concluded that a combined intervention of Dual-Task Training and Aerobic Exercise can enhance short-term memory. This improvement is attributed to increased blood flow and cerebral perfusion, ensuring the optimal distribution of nutrients and oxygen, alongside neuroplasticity that accelerates cellular regeneration in the brain. The impact of the combined Dual-Task Training and Aerobic Exercise is greater than that observed in the group receiving only Aerobic Exercise. This is because the addition of Dual-Task Training induces neurogenesis through distinct yet complementary mechanisms; physical exercise stimulates the proliferation of precursor cells, whereas cognitive stimulation enhances the survival of newborn cells.

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