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The effect of playing Onigokko on children's executive function and cardiovascular endurance in the early elementary school grades

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This study investigated whether continuously playing Onigokko, a game similar to tag, could enhance children's cognitive flexibility, a component of executive function, and improve cardiovascular endurance. The intervention group comprised 34 students enrolled in the second-grade A class of H elementary school in Y prefecture. The control group comprised 34 students enrolled in the second-grade B class at the same school. Cognitive flexibility was assessed using the Trail Making Test Task B (TMT-B), while cardiovascular endurance was measured using a 20-meter shuttle run. These measurements were taken for both groups before and after four weeks playing Onigokko with the intervention group. A two-way ANOVA was applied for each measurement item, considering the group (intervention and control groups) and measurement period (pre and post). A significant interaction was found between cognitive flexibility (TMT-B response time) and cardiovascular endurance (20-meter shuttle run count and maximal oxygen consumption [VO2Max]); thereafter, a simple main effect test (Bonferroni method) was conducted. The results revealed that the intervention group's cognitive flexibility (TMT-B response time) and cardiovascular endurance (20-meter shuttle run count and VO2Max) significantly improved post-intervention compared to the control group. These findings suggest that continuously playing Onigokko can significantly enhance both cognitive flexibility and cardiovascular endurance among early elementary school students.

Keywords Cognitive flexibility, Physical fitness, Tag

Exercise is important for improving physical fitness; however, the effect of exercise on higher-order cognitive functions, also known as executive functions, has recently been attracting attention. Executive function, which is the ability to achieve goals by engaging in higher-order cognitive and behavioral control, involves three components: inhibition, working memory, and cognitive flexibility[1]. Inhibition is the ability to control dominant and automatic responses according to context[2]. Working memory is the ability to store and process information temporarily and use the stored information[2]. Cognitive flexibility is the ability to change the perspective of attention and prepare cognitively for the next task rule[2]. It is widely accepted that executive function develops rapidly throughout childhood and adolescence in conjunction with the increasing demands of learning, schooling, and sociocultural participation[3]. Helping young children develop good executive function is important[4], as their executive function predicts academic achievement in areas including math and language arts, as well as better school readiness[5,6].

Several studies have shown that moderate-to-vigorous exercise can improve children's executive function[7,8]. A longitudinal study has revealed that children who engaged in moderate-to-vigorous physical activity at age 11 had better executive function at age 13[9]. Another study has shown that an aerobic exercise intervention of moderate-to-vigorous intensity for children aged 7 to 9 years old resulted in significant improvements in executive function, including inhibition and cognitive flexibility, as well as cardiovascular endurance compared to a control group[10].

Research on the effects of physical activity on executive function needs to extend beyond simple exercises that require minimal cognitive engagement, such as aerobic exercise[11]. In other words, complex exercises requiring high cognitive ability may be more effective at improving executive function than simple physical activities[11]. In this context, from a developmental perspective, play has many physical, emotional, cognitive, and social benefits[12]. Play is known to develop and enhance independence, social interaction, cooperation, imagination,

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creativity, language skills, working memory, ability to follow directions, problem-solving skills, emotional control, and physical fitness[13]. Nearly all of these skills are components of executive function, making play-based approaches an ideal means to develop executive function[14]. Therefore, play-based exercise that requires cognitive effort may be beneficial for implementing exercise interventions aimed at improving executive function in young children, particularly during a stage when the development of executive function is prominent.

The traditional Japanese game of Onigokko, which is similar to the English game of tag, is a simple physical game that originated in Japan more than 1,300 years ago and is still widely played throughout Japan today[15]. In one form of Onigokko, the players are divided into two roles, namely a demon and a child, and the demon chases the child while the child attempts to escape to avoid being caught by the demon[15]. Onigokko does not require any special equipment and can be easily enjoyed anywhere, such as on flat ground, fields, parks, forests, gymnasiums, or on the side of the road[15]. Because the rules are simple, it does not require a specially trained instructor and can be learnt immediately by children and adults alike[15]. Therefore, Onigokko involves physical activity through play that children can easily engage in during their school life. It has high cognitive demands, as it requires not only monotonous running movements but also constant instantaneous situational judgments, such as stopping and changing direction according to the situation. Therefore, Onigokko is considered to be suitable as an exercise that can be expected to improve the executive function of preschool and postschool children. Most participants engage in moderate-to-vigorous intensity physical activity, as it involves sprinting and moving quickly while players attempt to avoid or catch other players[15].

Cardiorespiratory endurance is an element of physical fitness that is related to how long one can continue exercising while taking in oxygen. It differs from other elements of physical fitness in that it improves when engaging in continued high-intensity exercise at 85–90% of your maximum heart rate[16]. Therefore, physical fitness, especially cardiorespiratory endurance, is expected to improve by playing Onigokko continuously. However, there have been no studies investigating the effects of playing Onigokko continuously on improving executive function or cardiorespiratory endurance.

This study aimed to clarify whether continuously playing Onigokko can effectively improve cognitive flexibility in executive function and cardiovascular endurance in physical fitness of early elementary school children, at a stage when the development of executive function is prominent. Given that Onigokko requires players to constantly demonstrate flexibility in their actions, this study focused on the cognitive flexibility domain in executive function. We adopted the Trail Making Test (TMT) as a cognitive flexibility task because its instructions are simple and it is time-efficient to perform[17]. We hypothesized that by continuously playing Onigokko, the intervention group would significantly improve their cognitive flexibility and cardiovascular endurance compared to the control group. This study is significant because it identifies a versatile exercise that can be easily enjoyed by children to improve their physical fitness and executive function, which play important roles in school readiness as well as long-term physical and mental health.

Method

Participants

The intervention group comprised 34 Japanese-speaking children (18 boys and 16 girls; mean age: 8.4 years ± 0.3) enrolled in second-grade A class in February 2024 at H Elementary School, which is a small, rural school in Y Prefecture that was randomly selected for the study. The control group comprised 34 Japanese-speaking children (20 boys and 14 girls; mean age: 8.4 years ± 0.3) enrolled in second-grade B class in February 2024 at the same elementary school as the intervention group. Table 1 shows the participants' demographic characteristics. Sample size calculations using G*Power 3.1 indicated that 34 children in each group (intervention and control) would provide a power ($1-\beta$) of 0.80. The calculations were based on an effect size of 0.17, two measurements, a correlation among repeated measures of 0.5, a nonsphericity correction of 1, and an α level of 0.05[18].

Procedures

Intervention group

Prior intervention studies in which improvements in executive function were observed have revealed the importance of repeatedly and continuously carrying out the intervention[2]. To improve executive function, moderate-intensity exercise interventions are recommended 3–4 times a week. Studies have shown that an 8-12-week exercise intervention can effectively improve children's executive function[19], likely because long-term exercise intervention involves repeated practice and continuous engagement of executive function[19].

In this study, during a four-week period between January and February 2024, Onigokko was played three times a week during 15 min of the 20-minute morning recess period at the ground of the elementary school attended by the participants. The exercise intervention was limited to four weeks after consulting with participants' homeroom teachers and considering their daily educational activities and the need to maintain

	All ($n = 68$)	Intervention group ($n = 34$)	Control group ($n = 34$)
	M ± SD	M ± SD	M ± SD
Age (years)	8.4 ± 0.3	8.4 ± 0.3	8.4 ± 0.3
Gender	38 boys and 30 girls	18 boys and 16 girls	20 boys and 14 girls

Table 1. Characteristics of subjects divided into intervention and control groups. M = mean; SD = standard deviation.

motivation. The participants were divided into two teams, red and white, to play Onigokko in a rectangular court of approximately 200 m^2 drawn on the elementary school's ground. The children in the red team clipped their red headband to the back of their pants (similar to tails), and the children in the white team similarly clipped their white headband. The team that captured more tails of the other team's color within a time limit was declared the winner. Children whose tails were taken were given tails of their own team's color by their teachers and could re-insert their own tails before restarting the game. To prevent injury, the children were not allowed to push or grab the other team's children. Two games of 5 min each were played, with 5 min in between games for rehydration and thinking about strategy. The participants' executive function and cardiovascular endurance were measured in January 2024 (pre-intervention), before Onigokko was conducted, and again in February 2024 (post-intervention), after the Onigokko intervention had been completed. The intervention was administered by the homeroom teacher.

Control group
While the intervention group played Onigokko, the control group spent 20 min of the recess indoors, on a voluntary basis. Specifically, they did things they could do indoors, such as reading, resting, and chatting with friends. As with the intervention group, executive function and cardiovascular endurance were measured in January 2024 (pre-intervention) and again in February 2024 (post-intervention). The children in the intervention group played Onigokko with those in the control group for the same period between February and March 2024 as an ethical consideration.

Measures
TMT-B was used to measure cognitive flexibility in executive function[20]. TMT comprises two tasks: Task A, which measures visual-motor search speed (TMT-A), and Task B, which measures a wide range of executive function, especially cognitive flexibility (TMT-B). In TMT-A, numbers from 1 to 25 are scattered across a sheet of paper, and the task is to connect these numbers in order with a line. However, in TMT-B, numbers from 1 to 13 and letters from "a" to "shi" (kana symbols or Japanese letters in a certain order like the English alphabet) are scattered across a sheet of paper, and the participants are required to connect the numbers and kana alternately and in order, as in "1-a-2-i-3-u." The response time is calculated for both tasks A and B. The shorter the response time, the better the performance[20].

In this study, students' performance on the TMT-B task was used as a measure of cognitive flexibility, a component of executive function. The reliability and validity of the TMT-B as an index for measuring cognitive flexibility has been confirmed, and the faster the reaction time on the TMT-B, the higher the cognitive flexibility[21]. In this study, participants made few errors when performing the task; because errors are often a secondary indicator in TMT, we chose to use reaction time as the primary index, in line with previous research[21].

To measure cardiovascular endurance, a 20-meter shuttle run was conducted, which is probably the most widely used field test for estimating cardiovascular endurance[22]. The shuttle run is simple, easy to perform, not overly time-consuming, requires minimal equipment, and can be used to test many individuals simultaneously. The 20-meter shuttle run comprises one minute of stepwise, continuous, and incremental speed running. The initial speed is 8.5 km/h, increasing by 0.5 km/h every minute[23]. Participants must run between two lines 20 m apart in time to an audio signal emitted from a pre-recorded compact disc. The test is terminated if the participant fails to reach the end line simultaneously with the audio signal on two consecutive occasions. The maximal oxygen consumption (VO2Max) level was calculated based on the number of 20-meter shuttle runs. The 20-meter shuttle run test is a valid and reliable test for predicting VO2Max[22], with a higher estimated VO2Max value indicating better cardiovascular endurance[22].

To reduce study bias, the researcher conducting the evaluation was blinded to the group allocation during the evaluation phase.

Ethical considerations
This study was conducted in compliance with the Declaration of Helsinki. The purpose and procedures of this study were explained in writing to the participants and their guardians, and informed consent was obtained. We assured them that they would not suffer any disadvantages if they did not consent, that they could withdraw their consent even after consenting, and that personal information obtained in the study would be handled with great care to prevent leakage. We obtained written approval for this study from all participants and their guardians. In conducting this study, an ethical review was conducted by the Research Ethics Committee of Yamaguchi University, to which the authors belong, and approval was obtained before the start of the study (approval number – 2022-095-01). The data collected in this study were coded and collected anonymously.

Data analysis
There were no missing data for the 68 participants in the intervention and control groups; therefore, the data of all participants were included in the analyses. The significance level was set at less than 5%. Normality tests were conducted for each measurement item to confirm the assumptions of the analysis of variance (ANOVA). For each measurement item, unpaired t-tests were performed to check for differences between the intervention and control groups at baseline. For each measurement item, a two-way ANOVA was conducted with group (intervention and control) and measurement time (pre and post) as factors. When a significant interaction was identified in the analysis, a simple main effect test was performed using the Bonferroni method to account for multiple comparisons. All analyses were performed using IBM SPSS Statistics for Windows version 27 (IBM, Armonk, New York, USA).

Measures	Intervention group					Control group					Main effect (time)	Main effect (group)	Interaction	Effect size
	N	pre		post		N	pre		post					
		M	SD	M	SD		M	SD	M	SD	*F*	*F*	*F*	η^2
TMT-A response time(sec)	34	60.2	3.0	58.9	2.5	34	61.6	2.4	59.8	2.5	32.01***	4.14	0.75	0.01
TMT-B response time(sec)	34	133.7	4.1	123.4	3.4	34	133.9	3.0	126.2	4.0	430.9***	3.57	9.44**	0.13
20 m shuttle run (count)	34	27.4	13.2	38.7	14.4	34	27.9	12.7	31.2	13.0	59.28***	1.29	17.62***	0.21
20 m shuttle run (VO2Max (ml/kg × min))	34	32.2	2.9	34.7	3.2	34	32.3	2.8	33.0	2.9	59.93***	1.33	17.77***	0.21

Table 2. The two-way ANOVA results for each measurement item. ** $p < 0.01$, *** $p < 0.01$. M = mean; SD = standard deviation.

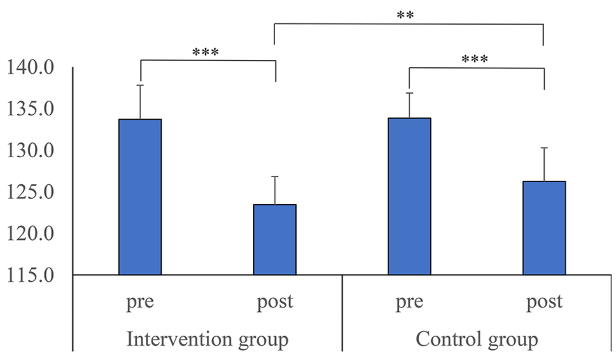

Fig. 1. Results of TMT-B response time (sec) where the interaction was significant. ** $p < .01$, *** $p < .001$.

Results

The Shapiro–Wilk test showed that the data gathered for each measurement item did not deviate from the normal distribution. Unpaired t-tests were performed to examine whether there were differences between the intervention and control groups at baseline for each measurement item, with no significant differences being found. Table 2 presents the ANOVA results for each measurement item for the participants of this study.

The two-way ANOVA showed significant interactions between "TMT-B response time (sec)" (F (1,66) = 9.44, $p < .01$, $\eta^2 = 0.13$), "20-meter shuttle run (count)" (F (1,66) = 17.62, $p < .001$, $\eta^2 = 0.21$), and "20-meter shuttle run (VO2Max (ml/kg × min))" (F (1,66) = 17.77, $p < .001$, $\eta^2 = 0.21$). According to conventional benchmarks, a small effect size is $\eta^2 = 0.01$, a medium effect size is $\eta^2 = 0.06$, and a large effect size is $\eta^2 = 0.14$[24]. Thus, the effect size of the interaction for the cognitive flexibility was medium to large and that for cardiovascular endurance was large. Simple main effects tests were performed using the Bonferroni method for TMT-B response time (sec), 20-meter shuttle run (count), and 20-meter shuttle run (VO2Max (ml/kg × min)).

For the TMT-B response time (sec), the intervention group (M = 123.4, SD = 3.4) showed significantly better performance compared to the control group (M = 126.2, SD = 4.0) ($p < .01$) in the post-test. In terms of within-group improvements, the post-test response time (M = 123.4, SD = 3.4) was significantly better ($p < .001$) than the pre-test response time (M = 133.7, SD = 4.1) for the intervention group; meanwhile, the control group fared significantly better ($p < .001$) in the post-test (M = 126.2, SD = 4.0) than in the pre-test (M = 133.9, SD = 3.0).

For the 20-meter shuttle run (count), the intervention group (M = 38.7, SD = 14.4) showed significantly better performance compared to the control group (M = 31.2, SD = 13.0) ($p < .05$) in the post-test. In terms of within-group improvements, the post-test count (M = 38.7, SD = 14.4) was significantly higher ($p < .001$) than the pre-test count (M = 27.4, SD = 13.2) for the intervention group; meanwhile, the control group fared significantly better ($p < .05$) in the post-test (M = 31.2, SD = 13.0) than in the pre-test (M = 27.9, SD = 12.7).

For the 20-meter shuttle run (VO2Max (ml/kg × min)), the intervention group (M = 34.7, SD = 3.2) showed significantly better performance compared to the control group (M = 33.0, SD = 2.9) ($p < .05$) in the post-test. In terms of within-group improvements, post-test VO2Max (M = 34.7, SD = 3.2) was significantly higher ($p < .001$) than pre-test VO2Max (M = 32.2, SD = 2.9) for the intervention group; meanwhile, the control group fared significantly better ($p < .05$) in the post-test (M = 33.0, SD = 2.9) than in the pre-test (M = 32.3, SD = 2.8). Figures 1, 2 and 3 depict the two-way ANOVA results for TMT-B response time (sec), 20-meter shuttle run (count), and the 20-meter shuttle run (VO2Max (ml/kg × min)), respectively, highlighting the significant interactions.

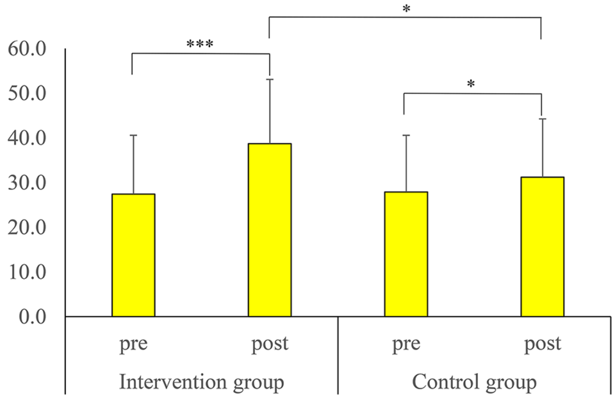

Fig. 2. Results of 20 m shuttle run (count) where the interaction was significant. $*p < .05$, $***p < .001$.

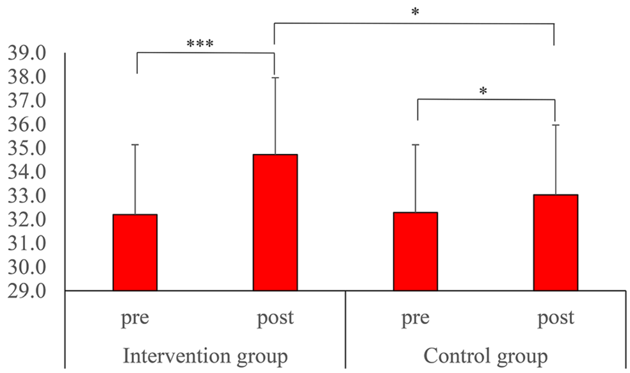

Fig. 3. Results of 20 m shuttle run (VO2Max (ml/kg × min)) where the interaction was significant. $*p < .05$, $***p < .001$.

Discussion

This study aimed to investigate whether playing Onigokko improves cognitive flexibility, a component of executive function, and cardiovascular endurance in early elementary school children, by comparing these pre- and post-test results in relation to a control group. The results revealed that the cognitive flexibility and cardiovascular endurance of the intervention group, who played Onigokko for 15 min three times a week for four weeks, were significantly better developed than those of the control group.

TMT-B performance is an indicator of cognitive flexibility because the task of alternating between numbers and letters involves set shifting, which requires cognitive effort[25]. The ANOVA results for TMT-B revealed that the cognitive flexibility of early elementary school children who received the Onigokko play intervention was significantly higher than that of the control group. The results of this study, which used Onigokko as a cognitively demanding exercise intervention of moderate-to-vigorous intensity, are consistent with those of previous studies[26,27] that demonstrate the effects of high-intensity physical activity interventions requiring high levels of cognitive engagement on cognitive flexibility in elementary school children. Recent intervention studies suggest that not all forms of physical activity are equally beneficial for executive function, and that a moderate-to-vigorous intensity and cognitively engaging physical activity may be more effective in improving executive function[28]. Increased cognitive demand induces cognitive engagement[29]. Cognitively demanding exercises activate brain regions responsible for executive functions, which are used to control higher cognitive processes[30,31]. Activation of these brain regions through participation in cognitively demanding exercises may provide cognitive benefits in limited areas of executive function[28]. The Onigokko intervention used in this study required participants to flexibly choose their actions based on their surroundings, such as the presence of enemies and allies[15]. Therefore, it is likely that the intervention group that played Onigokko had significantly higher cognitive flexibility than the control group.

In the present study, the ANOVA results for the 20-meter shuttle run revealed that the children in the early grades of elementary school who participated in the Onigokko intervention showed significantly greater gains in cardiovascular endurance than the control group. Continued moderate-to-high intensity exercise exceeding 85% of maximum heart rate is thought to improve cardiovascular endurance[32]. In fact, several studies on children have consistently shown that continued moderate-to-high intensity physical activity improves cardiovascular endurance[33–35]. A study on children aged 6 to 7 years, the same age as the participants of this study, have reported that the intervention group that received a moderate-to-vigorous intensity treadmill running intervention had significantly higher maximum oxygen uptake compared to the control group[36]. Similar results were observed in the present study. The exercise intervention in this study, Onigokko, required players to run at full speed while chasing or evading the opposing team, demanding continuous moderate-to-vigorous intensity activity[15]. Therefore, the cardiovascular endurance of the intervention group, who continuously performed moderate-to-vigorous intensity exercise by playing Onigokko, significantly improved compared to that of the control group.

Even in the control group, the scores for cognitive flexibility and cardiovascular endurance were significantly higher in the post-test than in the pre-test. Previous studies have reported that cognitive flexibility and cardiovascular endurance develop significantly during elementary school age[2,37]. Although the pre- and post-test measurements lasted about one month, it is believed that the developmental stage of the participants in the lower grades of elementary school contributed to significant growth in original cognitive flexibility and cardiovascular endurance during this period, which is why the post-test scores were significantly higher than the pre-test scores.

Strengths and limitations

There have been many intervention studies to effectively improve children's executive function in preparation for school[38,39]. While some previous studies have suggested that moderate-to-high intensity exercises are effective in improving children's executive function, it has also been observed that complex exercises that require cognition are more effective in improving executive function than simple exercises[11]. In this study, an intervention using the traditional Japanese children's game of Onigokko improved the cognitive flexibility and cardiovascular endurance of second-grade elementary school students to a significantly higher level compared to the control group. This study is highly significant as it provides new scientific evidence that Onigokko, a fun physical activity with relatively simple rules and requiring cognitive effort, is effective in improving executive function and cardiovascular endurance. The strength of this study lies in the fact that the participants, who were in the developmental stage of early elementary school, could improve their cognitive flexibility and cardiorespiratory endurance through the game-like exercise content of Onigokko, in which they were motivated to continuously engage.

In the present study, the sample size was relatively small, and all participants were elementary school children from the same area, which limits the generalizability of the findings. Future studies should secure a large sample size from diverse regions to examine the effects of Onigokko participation on improving executive function and cardiovascular endurance. Another limitation of this study is that it did not incorporate a randomized controlled trial, preventing us from clearly demonstrating the effects of the intervention. Furthermore, this study only measured cognitive flexibility as part of executive function. Future research should examine the effect of Onigokko intervention on other elements of executive function, such as inhibition and working memory.

A previous study demonstrates that an 8–12-week exercise intervention effectively improves children's executive function[19]. In this study, the exercise intervention was limited to four weeks to balance daily educational activities and sustain participants' motivation. The strength of this study lies in its improvement of cognitive flexibility even during the four-week exercise intervention period by using Onigokko as a moderate-to-vigorous intensity and cognitively demanding physical activity for kindergarteners. However, the intervention effect might have been greater if the exercise intervention period in this study had been longer.

Conclusion

This study examined whether an intervention group composed of early elementary school children that played Onigokko continuously would significantly improve their cognitive flexibility and cardiorespiratory endurance compared to a control group that comprised children from the same grade level. For this purpose, we employed ANOVA to examine the differences in performance in TMT-B and a 20-meter shuttle run between the intervention group, which played Onigokko three times a week for 15 min for four weeks, and the control group. The results revealed that the intervention group showed significantly greater improvement in both cognitive flexibility and cardiorespiratory endurance compared to the control group.

Data availability

The raw data used and analyzed during the present study is provided within the supplementary material.

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Declarations

Competing interests
The authors declare no competing interests.

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