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Original Article

The effects of an 8-week play-oriented model on motor coordination in early childhood: Evidence from educational settings

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Abstract
Motor coordination (MC) is essential for early childhood development, particularly in physical activities requiring whole-body movement. Play-based learning has emerged as a key strategy for enhancing student engagement, inclusion, and skill development beyond the preschool years. Game-based motor coordination (GBMC) learning is an effective pedagogical approach that promotes diverse learning results, encourages play-oriented participation, and enhances early motor skills and coordination. This study examined the differences in MC between an intervention group using the GBMC learning model and a control group without GBMC over an eight-week period in 7-year-old children. The intervention group (n=25) practiced GBMC for eight weeks, with physical education teachers facilitating GBMC learning through structured instruction. The week before and after, MC was assessed using the KTK3+, and the results were compared to those of a control group (n=27). Children in the intervention group showed more significant improvements in MC compared to the control group in balance beam (d = 0.11), jumping sideways (d = 0.15), moving sideways (d = 0.15), and eye-hand coordination (d = 0.17). This study found that the play-oriented model can improve MC over an eight-week period. Given the importance of well-developed MC, early childhood education and physical education teachers in schools should be taught how to implement a play-oriented model into their classes. To effectively implement a play-oriented model, school communities and teachers need a clear understanding of the concepts of play and learning. The roles and responsibilities of teachers are crucial for the educational benefits associated with this approach. This research can strengthen efforts to position child-centered pedagogy and play-oriented learning at the core of the preschool and primary school education system.
Keywords: motor coordination, child development, intervention, KTK3+, learning model

Introduction

Many experts in motor development (Bardid, 2016; Barnett et al., 2016; Gallahue et al., 2012) state that knowing motor competence (MC) is essential for remaining active throughout life. Concerning the importance of building stable MC, Clark and Metcalfe (2002) observed that the inability to grasp these skills may reduce children's opportunities to engage in physical activity (PA) as they grow, due to underdeveloped basic abilities. MC is considered one of the most important skills during childhood (Stanković et al., 2023). Focusing on MC in early childhood is essential for long-term obesity prevention and encouraging continued participation in PA (Lopes et al., 2012).

Obesity is an issue that must be addressed from an early age. Many countries undergoing economic transition, as well as Western countries, are experiencing an increase in childhood obesity (Lobstein et al., 2004). Obese children often exhibit reduced MC and endurance (Graf et al., 2004) and are more likely to demonstrate lower levels of MC (Okely et al., 2013). Ideally, teachers at school and parents at home should pay attention to preventing obesity in every child. Indicators of obesity include a lack of physical activity, poor fitness levels, and low motor skill quality in children (Lopes et al., 2012).

MC has a positive association with various aspects of health in early childhood, including PA, healthy weight status, cardiorespiratory fitness, endurance, and muscle strength (Cattuzzo et al., 2016; Lubans et al., 2010). In addition, several studies have revealed a consistent relationship between motor competence and physical activity in the development of every child (Holfelder & Schott, 2014; Robinson et al., 2015). Furthermore, Lubans et al. (2010) reported that MC positively influences overall health and increases PA levels. Thus, motor skills are essential to children's development (Bakhtiar et al., 2023; Lucas et al., 2016), and improving MC in preschool-aged children supports their learning process (García-Marín & Fernández-López, 2020).

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Teachers play a pivotal role in designing effective teaching practices to achieve learning objectives within the educational context. The importance has grown alongside the global push to enhance holistic skills, learning outcomes, and curricula (Darling-Hammond, 2006). Learning through play is a pedagogical approach that promises to achieve broader learning outcome goals and increase early childhood PA participation (Marbina et al., 2011). Early childhood is a crucial period for the holistic development of a child, during which MC stimulation is essential, as the nervous system undergoes rapid growth. Research indicates that appropriate stimulation can accelerate motor development (Mardiansyah et al., 2024; Sutapa et al., 2021). Play is an effective method for supporting children's motor skills development, and when children spend more time playing, it contributes to good physical health (Sutapa et al., 2021). Spanaki et al. (2014) mention that developing a learning model focused on fine and gross motor skills positively impacts the motor skills of children at the early childhood education (ECE) and primary school levels. Thus, motor exercise and activities will benefit all children with delays and have an effect on academic achievement (Chen et al., 2021). Children who play more passively, such as using touch screens on cell phones, are at risk of decreased motor skills (Cristia & Seidl, 2015). Play is foundational for fostering growth and development in ECE (Pramling Samuelsson & Björklund, 2023). Globally, preschool, pre-primary, and other curricula for primary school education highlight the importance of play (Danniels & Pyle, 2018). For example, UNICE (2018) released a report emphasizing the second target of Sustainable Development Goal (SDG) 4, which aims for all children to have access to quality pre-primary development, care, and education by 2030 to prepare them for primary education. The key message of this report is that "learning through play" is pivotal in early childhood development (ECD), which gives children autonomy and control over their experiences. Children who engage in play-oriented approaches are believed to develop a range of skills, including intellectual, emotional, social, and physical abilities.

Learning through play is an important strategy for promoting student engagement in the learning process and fostering holistic skill development from early school education (Parker et al., 2022). Policymakers, researchers, and educators have advocated for the concept that learning through play is suitable for children's developmental stages (Mardiansyah et al., 2024). Play utilizes the curiosity of school-age children, helping to ease the often challenging transition from preschool to formal schooling. However, there is still limited evidence and practical guidance on effectively implementing learning through play in formal school environments and the factors contributing to its success. Similarly, in Indonesia, learning through play has not yet become a mainstream educational approach in schools. In this study, we used the game-based motor coordination learning (GBMC) model developed by Mardiansyah et al. (2024). The model presents a variety of engaging exercises that incorporate games from various MC-related sports. From a cognitive perspective, the development of the GBMC model has focused on learning at the level of higher-order thinking skills (HOTS). By offering high-quality game-based learning, the GBMC pedagogy helps to meet teaching quality expectations.

The play-based learning method provides a strong basis for children to explore themselves with nature. Overall, experts in anthropology, neuroscience, and psychology have conducted research to examine this phenomenon (Irmawita et al., 2024; Whitebread et al., 2012). More than a century ago, Dewey (1933) established a link between children's natural experimentation during play and the process of scientific inquiry. Smolucha and Smolucha (2021) emphasize the importance of understanding play's positive impact; play influences children's cognitive abilities, self-awareness, speech development, and self-regulation. Furthermore, neurologists have found that play helps children effectively enhance the brain's prefrontal cortex and stimulates the production of proteins responsible for neuron differentiation and the growth of new synapses (Casey & MacPhail, 2018). On the other hand, the absence of play negatively affects brain development and problem-solving (Pellis et al., 2014). Play interventions commonly support children with challenges in developing social-emotional skills, overcoming movement delays, and fostering positive peer relationships (Mardiansyah et al., 2024). In recent years, there has been debate about the quality of teaching and learning in ECE, particularly concerning the role of play (Mardiansyah et al., 2024). In Australia, increasing pressure to formalize ECE in order to improve educational outcomes has led to a reduction in playtime for children in classrooms. The trend has been observed in both Australia and internationally (Sgrò et al., 2022). Although there is a significant body of research highlighting the importance of play in children's learning during their early years (Danniels & Pyle, 2018), there is limited research examining the connection between play and learning in early primary education. Meanwhile, in Indonesia, the play method remains a relatively new approach in formal education. Many teachers still lack a comprehensive understanding of how to implement play-oriented models effectively.

Research is needed focusing on the potential of play-oriented methods to improve MC skills in primary schools. Thus, it is essential to understand play's role in learning and promote play as an effective method for children's development. With this understanding, it will make a positive contribution to the evaluation of learning in early childhood education (ECE) and physical education in primary schools. In addition to an effective learning model, a reliable assessment tool is essential to evaluating the learning process's outcomes. This study used the Körperkoordinationstest für Kinder (KTK3+) to assess MC skills. Therefore, the primary objective of this study is to assess the impact of an intervention on 7-year-olds to improve their MC over an eight-week period using a play-oriented model, in which lessons are designed around a series of games specifically focused on enhancing MC and determine whether there are any differences between genders. It was

hypothesized that children would increase their MC over the eight-week period as they were instructed to achieve clear goals through MC games conducted individually or in groups. No specific expectations were made regarding the effect of gender on increasing MC in 7-year-olds.

Methods

Design

A total of 52 children aged 7 years from two primary schools in western Indonesia participated in this study. One school was assigned to the intervention group, while the other served as the control group. The participants included 29 girls (56%) and 23 boys (44%). In both schools, physical education classes were delivered by qualified teachers. Informed consent was obtained from both the schools and the parents. After obtaining ethical approval from the Universitas Negeri Padang and local authorities, two schools were recruited, one hosting the intervention and the other serving as the control.

This study divided participants into two groups (GB-MC vs. non-GB-MC) as the primary data for implementing the developed model. During the eight-week, the PE class in the intervention group participated in GB-MC learning sessions twice a week for 45 minutes each. In contrast, the control group attended regular physical education classes without any additional interventions.

Intervention

This research was designed based on prior research utilizing play-based learning approaches to improve MC and motor skills in primary school children (Mardiansyah et al., 2023; Platvoet et al., 2016; Sutapa et al., 2021). A GB-MC program was developed to enhance an essential factor, the foundation of sports skills, which has not received much attention in motor coordination. The program enhances enjoyment by promoting social connectedness, facilitating fun learning, improving cognitive abilities, and increasing perceived competence.

Our model focuses on improving MC in children at 7 years old through games that emphasize communication, social skills, cognitive development, joint strategy building, planning, and trust. All games can be played using readily available and low-cost equipment. Teachers and research assistants will implement the games developed in the GBMC. Each GBMC game requires two repetitions, each lasting less than 30 minutes. The intervention will be conducted during regular physical education lessons, with each session lasting 45 minutes.

Procedure

Participation in the intervention was included in the mandatory elementary school physical education class. Teachers were recruited through email and direct phone calls. We contacted six physical education teachers, and three agreed to assist in implementing the GBMC in this study. All game formats and model explanations were provided to the teachers to ensure they understood the procedures for conducting research with both the intervention and control groups. However, due to limited permission from the school, this study could only implement two teachers teaching in the GB-MC program and one teacher in the no GB-MC program.

The study intervention used the Körperkoordinationstest Für Kinder (KTK3+) test to measure motor coordination performance at the pretest and posttest. The KTK3+ test is valid and reliable for assessing motor coordination performance. The KTK3+ aims to evaluate the motor coordination of children and adolescents, the use of KTK3+ (Kiphard & Schilling, 1974; Novak et al., 2017) is complemented by a catching and throwing task (Platvoet et al., 2018) that assesses hand-eye coordination.

1. **Balance Beam (BB): Children walk backward barefoot on a 3-meter-long beam. Each child walks backward on beams with 6 cm, 4.5 cm, and 3 cm widths. Children are given three attempts to walk backward on each beam, with a maximum of eight steps allowed per trial.**
2. **Jumping Sideways (JS): Children perform two-footed sideways jumps (left and right) over a beam placed in the center. The task is repeated twice within 15 seconds. The total number of jumps from both attempts is counted, and the sum of these jumps is recorded as the final result.**
3. **Moving Sideways (MS):** The child begins by standing with both feet on one of two wooden platforms (25 cm x 25 cm x 5.7 cm) and moves across the floor within 20 seconds by alternating steps between the two platforms. The child steps from one platform to another and continuously repeats the movement. The total number of successful moves is recorded and summed across two trials.
4. **Eye-hand coordination (EHC):** Children stand behind a line 1 meter away from the wall, then throw a ball at the wall that has been given a target. Initially, the child throws the ball with their right hand and catches it with their left hand, then immediately throws it back with their right hand and catches it with their left hand, continuing this movement for two attempts within 30 seconds. The most catches are seen from the two attempts and recorded as the final result.

The participants were given instructions on the test procedures before starting each subtest. In accordance with the guidelines, all participants completed the tasks barefoot. The administration, scoring, and calculation of the KTK3+ test for children in Indonesia were carried out following the official manual. The raw scores from the overall KTK3+ test and its subtests were utilized for data analysis.

Data Analyses

The KTK3+ subtests in 7-year-old children, and the mean and standard deviation of the pretest and posttest results were calculated, differentiated by group (control and intervention) and gender. An analysis of variance (ANOVA) was conducted to examine differences in KTK3+ scores over time between the intervention and control groups and across genders. In the between-subjects analysis, group effects were assessed to identify differences in mean scores between the control group and the intervention group at pretest and posttest. The differences were analyzed using nonparametric tests, with intergroup differences (control vs. intervention) assessed through the Mann-Whitney U test and intragroup differences evaluated using the Wilcoxon test.

The interaction effect between the group and measurement was analyzed to assess the differences between the groups over time. All statistical tests were given a significance level of 0.05.

Results

The study included 25 students in the intervention group (12 males, 13 females) and 27 students in the control group (11 males, 16 females). All participants reported complete data for both pretest and posttest conditions.

Significant main effects were found for the group (Wilks' $\lambda = 0.49$; $F = 5.25$; $p < 0.001$; partial $\eta p^2 = 0.506$) and the interaction between gender and group (Wilks' $\lambda = 0.69$; $F = 2.34$; $p < 0.05$; partial $\eta p^2 = 0.313$). Additionally, significant main effects were also observed in the intervention group by ANOVA for the BB ($F(1, 48) = 10.75$; $p < 0.05$; partial $\eta p^2 = 0.183$), JS ($F(1, 48) = 14.69$; $p < 0.001$; partial $\eta p^2 = 0.234$), MS ($F(1, 48) = 14.78$; $p < 0.001$; partial $\eta p^2 = 0.235$), and EHC ($F(1, 48) = 7.57$; $p < 0.05$; partial $\eta p^2 = 0.136$).

A significant interaction was found between group and gender ($F(1, 48) = 9.50$; $p < 0.05$; partial $\eta p^2 = 0.165$) for the MS, with boys in the intervention group showing significantly higher average scores than boys in the control group. No additional significant interaction effects were observed between pretest and posttest scores across the subtests.

Table 1. Raw scores for the four KTK3+ subtests and the overall KTK3+ scores presented for boys, girls, and the total group of children.

Variable	Intervention Group				Control Group			
	Pretest		Postest		Pretest		Postest	
	M1	SD	M1	SD	M2	SD	M2	SD
Overall								
Total	127.3	16.6	149.9	14.2	128.4	16.1	127.9	16.8
Boys	130.5	20.7	153.1	19.0	128.7	17.8	128.8	14.0
Girls	124.3	11.7	147.0	7.3	128.2	15.5	128.6	19.2
Balance Beam								
Total	56.8	10.3	64.8	8.3	58.1	6.9	57.4	7.3
Boys	54.8	11.7	63.2	9.4	60.2	7.3	57.8	7.5
Girls	58.7	8.8	66.2	7.3	56.6	6.3	57.1	7.3
Jumping Sideways								
Total	37.8	5.5	43.8	6.5	37.3	5.0	37.0	6.9
Boys	39.3	7.3	45.9	8.4	37.2	5.3	35.5	4.7
Girls	36.5	2.9	41.8	3.3	37.4	5.0	38.0	8.1
Moving Sideways								
Total	30.5	4.8	35.8	3.9	30.7	5.2	30.9	5.2
Boys	32.9	4.4	37.3	3.8	28.7	4.8	31.0	5.0
Girls	28.2	4.2	34.5	3.7	32.1	5.1	30.9	5.5
Eye-Hand Coordination								
Total	2.2	4.0	5.6	4.3	2.3	4.5	2.6	3.5
Boys	3.5	5.2	6.7	5.9	2.6	5.4	2.6	2.5
Girls	0.9	1.3	4.5	1.7	2.1	3.8	2.6	4.1

The increase in KTK3+ pretest to posttest scores is shown in Figure 1. The mean pretest scores for the intervention group ($M = 127.3$, $SD = 16.6$) and the control group ($M = 128.4$, $SD = 16.1$) were comparable. However, the intervention group showed a significant increase in overall KTK3+ scores ($M = 149.9$, $SD = 14.2$) compared to the control group ($M = 127.9$, $SD = 16.8$) in the postest.

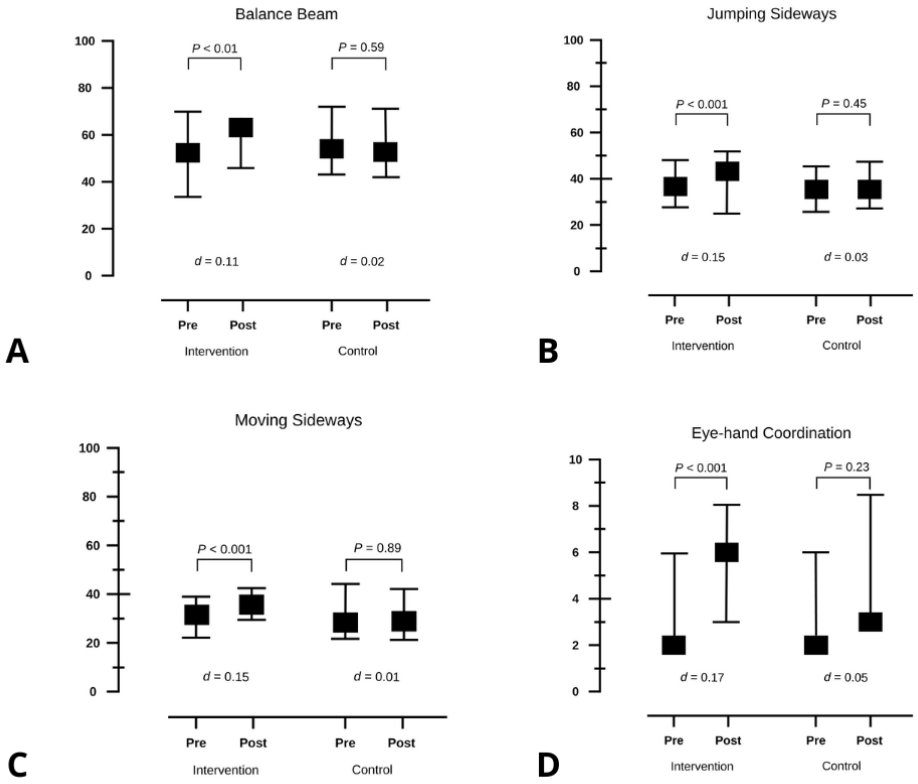

Figure 1. Performance variations in each motor coordination test—balance beam (A), jumping sideways (B), moving sideways (C), and eye-hand coordination (D) were analyzed for 7-year-old children participating in an 8-week game-based motor coordination program. Results are presented as median, minimum, and maximum values. Intergroup differences were assessed using the Mann-Whitney U-test, while intragroup (pre- and post-intervention) differences were evaluated using the Wilcoxon test. Additionally, effect sizes (Cohen's d) were calculated for both the intervention and control groups to compare pre-and post-intervention outcomes.

Over the eight-week period, the interaction between KTK3+ score and group revealed that the intervention group demonstrated more significant improvement in mean scores compared to the control group $F(1, 48 = 5.25$, $p < 0.001$, Wilks' Lambda = 0.49. The 7-year-old children sampled in the intervention group performed better in all four subtests of BB ($F(1, 48) = 10.75$, $p < 0.05$), JS ($F(1, 48) = 14.68$, $p < 0.001$), MS ($F(1, 48) = 14.77$, $p < 0.001$), and EHC ($F(1, 48) = 7.57$, $p < 0.05$).

As presented in Table 1, children in the intervention group demonstrated an average increase (22.6 ± 15.4) in their overall KTK3+ score, while those in the control group showed an average decrease (-0.5 ± 16.45).

Discussion

The primary objective of this study was to determine the extent to which 7-year-old children improved their MC over an eight-week period during which the GBMC learning model was implemented and to examine whether differences between the two groups of this research (intervention and control), and therefore we accept the research hypothesis.

Our results showed that 7-year-old children in the intervention group demonstrated significantly greater improvements in MC across all KTK3+ subtests over the eight-week period compared to the control group (see Table 1). Specifically, we observed an average increase of 22.6 in the overall MC score when assessing the impact of the intervention. We believe this model is novel in Indonesia, as research in this area remains limited. This study introduces a fun and effective play-based learning model primarily focusing on enhancing MC skills. Moreover, this model has the potential to be applied not only in physical education lessons in elementary schools but also by teachers in ECE settings.

The greater increase in mean KTK3+ scores from pre- to post-test in the intervention group was compared to the control group who attended the GBMC learning model at school. The importance of utilizing game-based learning strategies to improve FMSC has been previously demonstrated among children (Altinkök, 2016; Sutapa et al., 2021). On average, the improvement in pretest-to-posttest scores across all KTK3+ subtests in the intervention class was more significant than in the control group. Providing an appropriate learning model

is essential to enhancing specific targeted skills. However, the GB-MC model not only improves MC but also positively influences other motor skills, as it is designed to support holistic motor development. The results of our study align with the findings of the systematic review and meta-analysis conducted by Logan et al. (2012) and Morgan et al. (2013), which indicate that MC interventions are effective. Teachers can use the model developed in this study as a reference for the learning process in lower-grade primary schools (ages 7-9) to enhance MC and prevent related issues. Additionally, this approach introduces an element of fun to the lessons, helping children remain engaged and motivated. However, this claim is not yet fully supported by empirical evidence from testing. The authors believe that the success of this intervention is attributable not only to well-planned and enjoyable lessons but also to the clarity of instructions, making them easy for each child to follow throughout the learning process.

During the eight-week implementation of the GBMC learning model, children in the intervention group participated in two 45-minute sessions each week. The PE teachers in the intervention group were instructed to guide the children through a series of structured games, combining elements from various sports to enhance coordination skills. Other studies have shown the importance of play-oriented model for performance, creative thinking, innovation (Pramling Samuelsson & Björklund, 2023), skill-specific exercises (Platvoet et al., 2016), and physical and motor development (Mardiansyah et al., 2024) . This combination of engaging and playful methods is believed to stimulate learning and improve MC performance despite the relatively limited amount of time children in the intervention group spent participating in the GBMC game series (two sessions of 45 minutes each). For 7-year-olds, there were no significant differences in the improvement of MC between boys and girls on any of the KTK3+ subtests. This outcome aligns with findings that gender differences in physical performance generally become more pronounced during puberty, driven by variations in physical development (Ahnert et al., 2009; Vandorpe et al., 2012).

Our study suggests that 7-year-old children are at a more optimal developmental stage for improving their MC performance compared to younger children. This finding is consistent with Platvoet et al. (2016), who stated that the more significant improvement in MC performance among 7-year-olds can be attributed to their enhanced comprehension of task demands and lesson goals. In the current study, 7-year-old children were already at the end of the early childhood phase. It is possible that 7-year-olds benefit more from a play-oriented environment, as they can better comprehend teacher instructions, reflect on their performance, and independently think through problems when necessary. Thus, to explain the difference in performance, it is expected that 7-year-olds participate in more deliberate practice (Nobre et al., 2017).

In Indonesia, most children remain insufficiently motivated to engage in PA and are not yet involved in organized sports. This study did not gather information on the extent to which children practiced their MC outside of PE classes or on environmental factors that might influence their motor development. These factors include physical aspects (e.g., opportunities for outdoor play and access to school transportation) and social factors (e.g., parental involvement and peer interactions). These factors may, however, contribute to individual differences in MC performance improvement (Mardiansyah et al., 2023). Children who showed greater improvement also practiced motor coordination more outside of PE classes. Although previous research has highlighted the influence of environmental factors on MC improvement (Platvoet et al., 2016), further research is needed to understand these relationships better.

Moreover, the findings indicate that a play-oriented model significantly enhances coordination skills in early childhood. To effectively implement play-based teaching methods, school communities need a clear understanding of the concepts of play and learning, the roles and responsibilities of both children and teachers and the educational benefits associated with this approach (Parker et al., 2022). This research can serve as a starting point for reflection and advocacy that places child-centered pedagogy at the center of the pre-primary education system. Policies, implementation plans, teacher training programs, resource allocation, and quality assurance strategies for ECE should align with the increasing evidence that active, play-based learning environments offer a crucial, developmentally appropriate foundation for academic success and lifelong achievement.

This study was limited by its non-randomized design, lack of ethnic diversity, and the relatively small sample size of intervention and control groups. Future studies should use the GB-MC model in larger samples and diverse regions.

Conclusion

In conclusion, this study has demonstrated that a play-oriented model can improve MC within an eight-week period. Children who did not experience a play-oriented model showed less improvement in their MC, suggesting that it can be pivotal in fostering motor development in early childhood. This approach promotes MC and encourages active engagement and participation, which are essential for overall child development. Given the importance of well-developed MC performance, ECD and PE teachers should be trained to integrate play-oriented models into their classes and curricula to optimize learning outcomes holistically. For future research, we recommend conducting longitudinal studies to explore the long-term effects of the play-oriented model on children's MC, fundamental motor skills, physical activity, and physical fitness development, including a broader age range and various social and cultural backgrounds.

Competing Interests

Rembulan Catra Banyu Biru, Vevi Sunarti, Xiaoyu Zhang, and Arischo Mardiansyah declare that they have no conflicts of interest concerning the content of this study.

Author Contributions

Conceptualization: Rembulan Catra Banyu Biru, Arischo Mardiansyah
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Writing - review & editing: Rembulan Catra Banyu Biru, Arischo Mardiansyah, Xiaoyu Zhang

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