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Effects of rule-reversal ball games on executive function and motor coordination in boys aged 6–7 years

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Abstract

Background and Study Aim Executive functions and motor coordination are components of children's cognitive and motor development. Cognitively engaging physical activity is used within physical education to support cognitive engagement and motor skill development. Despite the application of such activities, their relative effectiveness in improving executive function and motor coordination in the early school-age group remains a matter of practical interest. The purpose of this study was to determine whether the use of rule-reversal ball games as part of the physical education curriculum in boys aged 6–7 years would improve executive functioning and motor coordination.

Material and Methods An experiment using a cluster randomized controlled design was performed at 8 private primary schools with 304 male participants aged 6–7 years. The experimental group (EG) took part in an 8-week rule-reversal ball games program during physical education (P.E.) classes. The control group (CG) participated in their usual P.E. classes. Executive function was assessed using the Head-Toes-Knees-Shoulders Revised (HTKS-R) test. Motor coordination was assessed using the Körperkoordinationstest für Kinder (KTK) test. Between-cluster adjusted regression analyses with cluster-robust standard errors were used to evaluate the data.

Results The experimental group achieved significantly higher post-intervention scores in executive function and in several motor coordination components (Walking Backward, Jumping Sideways, and Moving Sideways). No significant improvement was observed for Hopping for Height.

Conclusions Incorporating rule-reversal movement games into physical education may offer a successful means of supporting executive function development in boys aged 6–7 years. This approach may also enhance their ability to perform coordinated motor movements.

Keywords: behavioral self-regulation, inhibitory control, cognitively engaging physical activity, motor competence, HTKS-R, childhood motor development

Introduction

The development of cognitive and motor abilities during early school years forms a foundation for children's functioning in educational and physical contexts. Executive functions and motor coordination are interrelated processes that contribute to behavior regulation, adaptation to task demands, and the execution of structured movements. Within physical education settings, activities that require simultaneous cognitive engagement and motor execution impose additional demands on attention, inhibition, and coordination. Such combined demands create conditions in which children must continuously adjust their actions, follow changing rules, and maintain control over movement patterns.

Executive functions are a set of higher-level cognitive functions that enable individuals to regulate behavior, control attention, and adapt their actions in response to changing task requirements, among other processes [1]. The three core areas of executive function are inhibition, working memory, and cognitive flexibility. They are essential components of children's early learning, behavioral regulation, and academic readiness, especially in the early years of school [2]. Many studies have shown that executive functions develop rapidly during early childhood and the first years in a primary educational setting. Therefore, early childhood represents a developmental period during which environmental and educational supports can affect cognitive development [3]. A key tenet in current developmental models is that cognitive and motor development are interrelated. Children who acquire motor competence and demonstrate coordination skills may engage more effectively in cognitively challenging learning activities [4].

Evidence from an expanding number of

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studies indicates that physical activity influences executive function development in children. When children engage in movement-based activities, they are required to control attention, suppress inappropriate behavior, and respond to changes in task demands. Thus, movement-based activities engage core executive functions in real time [5]. Results from intervention and meta-analysis studies show that structured physical activity programs delivered during childhood can improve cognitive outcomes such as executive function and academic achievement [6]. Recent literature indicates that, in addition to the amount of physical activity, the cognitive demands of the activity contribute to its cognitive effects. Activities that involve rapid decision-making, rule shifting, or changing environmental cues place higher demands on executive processes and provide increased cognitive engagement for children [7]. For this reason, school physical education is considered an environment in which physical movement and cognitive processes can be integrated during activity.

Motor skills represent another aspect of child development that is related to cognitive outcomes and behavior. The ability of children to coordinate their bodies is referred to as motor competence and enables participation in physical activities and interaction with the physical environment [8]. Evidence indicates that motor competence and executive function follow similar developmental trajectories. Both involve processes related to planning, control, and the regulation of goal-directed behavior [9]. Empirical studies have reported a positive association between motor coordination and executive functioning. Children with higher levels of motor competence tend to perform better on measures of inhibitory control, cognitive flexibility, and working memory [4]. These findings indicate that movement experiences that simultaneously engage cognitive and motor systems during childhood may be relevant.

The concept of integrating cognitive demands into physical activity has gained attention in recent years. The term “cognitive engagement in physical activity” refers to the inclusion of mental challenges within movement tasks, requiring children to think while performing physical actions [10]. In such activities, children use both motor execution and information processing based on visual and auditory input. During task performance, they must adapt to changing rules, interpret environmental cues, and adjust behavior according to task demands. These conditions place simultaneous demands on executive control processes and motor coordination. Recent intervention studies indicate that incorporating cognitive challenges into physical activity can enhance executive functions, as children are required to continuously adjust their actions in response to multiple cues and changing movement conditions [11]. Physical education classes provide a context in which such activities can be implemented through structured movement tasks during childhood.

Executive functioning and coordinated movement may depend on shared mechanisms, including response inhibition, action planning, and the control of goal-directed behavior [12]. Systematic reviews and empirical studies report a positive association between executive functioning and motor competence in children, indicating that improvements in coordinated movement may be linked to higher-order cognitive processes [4]. At the same time, research on cognitive engagement during physical activity has primarily focused on cognitive outcomes, with limited attention to its combined effects on motor coordination development. Meta-analytic evidence indicates that participation in physically active tasks requiring cognitive effort is associated with improvements in executive functions, including inhibitory control and cognitive flexibility [10,13].

Analysis of research findings has shown that executive functions and motor coordination are interconnected processes that can be influenced through cognitively engaging physical activity. Previous studies on physical activity programs have primarily examined executive functioning in isolation, while the relationship between executive functioning and motor coordination performance has been less frequently addressed. At the same time, the integration of coordinated movement tasks with cognitive challenges within physical education has been considered, although their combined application in structured school settings remains limited in practice. In this context, physical education provides conditions for implementing movement tasks that require both cognitive control and coordinated actions. One such approach involves rule-reversal movement games, in which children are required to inhibit automatic responses and adjust their behavior according to changing rules. The application of such activities within regular physical education classes creates a basis for examining their combined influence on cognitive and motor processes in boys aged 6–7 years.

The purpose of this study was to determine whether the use of rule-reversal ball games as part of the physical education curriculum in boys aged 6–7 years would improve executive functioning and motor coordination. In accordance with this objective, it was hypothesized that participation in rule-reversal ball games would lead to greater improvements in executive functions compared to regular physical education classes. It was also hypothesized that the intervention would result in improvements in selected aspects of motor coordination in the experimental group relative to the control group.

Materials and Methods

Participants

The participants for this study were recruited from eight private primary schools for boys located in Samarra, Iraq, during the first semester of the 2025–2026 academic year. The study population was defined based on the total number of private primary schools for boys in Samarra at that time. All eligible boys from first-grade classes, aged 6 or 7 years at the time of the study, were recruited using a whole-class recruitment method. Thus, each participating school had one first-grade class, and all students who met the criteria of being in first grade and aged 6 or 7 years were invited to participate.

There were initially 333 students who were determined eligible for assessment. Due to lack of parental consent, health-related conditions, absence during baseline testing, and ineligibility based on the HTKS-R administration criteria, 14 students were excluded from baseline assessment. Thus, a total of 319 students completed the pre-intervention assessment.

During the intervention phase, 15 participants dropped out due to absence, transfer to other schools, or incomplete post-intervention assessments. In total, 304 participants were included in the final analytic sample, all of whom attended one of the eight participating schools.

The final sample included 152 children in the experimental group and 152 in the control group, with cluster sizes ranging from 34 to 42 participants across schools.

Eligibility Criteria

Children were eligible to participate if they:

(1) were enrolled in the first grade in one of the participating schools,
(2) were aged between 6 and 7 years,
(3) regularly attended physical education classes, and
(4) provided written informed consent from their parents or legal guardians.

Children were excluded if they:

(1) had health conditions that limited participation in physical activity,
(2) were absent during baseline assessment, or
(3) did not meet the administration requirements of the HTKS-R task.

To ensure sufficient exposure to the intervention program, participants were required to attend at least 80% of the intervention sessions. Only children who completed both the pre-intervention and post-intervention assessments were included in the final analytic sample.

Ethical Considerations. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Research Ethics Committee of the University of Samarra (No. 19, June 2, 2025). Written informed consent was obtained from parents or legal guardians, and verbal assent was obtained from the participating children. Participation was voluntary, and data confidentiality was ensured.

Study Design

Randomization. Randomization was conducted at the school (cluster) level to avoid contamination between participants within the same educational environment. Each participating school had one first-grade class, and all eligible students within that class received the condition assigned to their school. The eight participating schools were assigned identification numbers, and a computer-generated random number sequence was used to allocate four schools to the experimental condition and four schools to the control condition. Randomization was performed prior to baseline assessment to ensure that participant recruitment and data collection procedures were not influenced by group allocation. Because the intervention was implemented during regular physical education lessons, blinding of participants and teachers was not feasible. However, all outcome assessments were conducted using standardized testing procedures across schools to maintain consistency in data collection.

Intervention Program

Children in the experimental group were enrolled in a program called rule-reversal ball games, which was implemented during regular physical education classes. Physical education teachers delivered the intervention sessions, and the research team supervised their implementation. The traditional physical education program was modified to include cognitive challenges integrated with movement, requiring children to respond to changing rules during ball-related activities.

A total of 16 sessions were conducted over 8 weeks, with two sessions per week. Each session lasted approximately 40 minutes and was divided into three segments: a warm-up phase, station-based rule-reversal ball games, and a moderate-paced cool-down period.

Six activity stations were arranged along a movement lane measuring 15 m × 2 m. Two children performed tasks at each station and rotated every five minutes, allowing repeated practice across all stations while maintaining a consistent session duration. Each session followed a station-rotation format, with brief transition periods between stations.

Adjustments were made throughout the intervention to maintain participant engagement and increase task complexity. These included modifications to movement length and activity type while preserving the core principles of rule-reversal tasks.

Each station included a specific rule-reversal challenge requiring children to produce responses opposite to visual cues while moving or manipulating balls. Size reversal tasks required children to select or exchange a ball of opposite size to that indicated. Color reversal tasks required selection of a ball of opposite color. Directional reversal tasks required children to move in the opposite direction to that indicated by a visual signal.

Surface-based rule reversals were incorporated using concave, flat, and convex pathways with gradual height variations of approximately 20 cm. These surfaces were color-coded to contrast with the surrounding floor to improve visibility and safety during movement.

Children were also required to manipulate and transport the ball using the opposite hand indicated by visual cues. These tasks required suppression of automatic responses and execution of alternative actions while performing coordinated movements such as running, carrying, throwing, or placing a ball into a target.

The activities were adapted to match the developmental characteristics of children aged 6–7 years and to engage both motor coordination and executive function processes, particularly inhibition and cognitive flexibility. A pilot session was conducted prior to the intervention to ensure clarity of instructions, safety of equipment, and feasibility of the activity stations.

Intervention fidelity was monitored using session logs completed by physical education teachers and reviewed by the research team. Attendance records indicated that participants attended more than 90% of the scheduled sessions, reflecting high adherence to the program.

Control Condition. In the control group, regular school teachers continued to deliver physical education lessons using the standard curriculum implemented at the participating schools. Students in the control condition participated in two physical education lessons per week over the eight-week study period, consistent with the experimental group. However, they did not take part in rule-reversal ball game activities. The lessons consisted of standard physical education activities, including general warm-up exercises, basic movement tasks, and simple ball games without rule-reversal cognitive challenges.

Executive Function (HTKS-R)

Executive function was assessed using the Head–Toes–Knees–Shoulders Revised (HTKS-R) task, a widely used behavioral measure of self-regulation and executive function in early childhood. The task assesses key executive processes, including inhibitory control, working memory, and cognitive flexibility, through rule-based motor responses [14, 15]. In this task, children are required to perform the opposite action to a verbal instruction (e.g., touching knees when instructed to touch shoulders), thereby engaging multiple executive processes simultaneously.

The HTKS-R was administered individually to each child in a quiet room within the school to minimize distractions. The assessment was conducted by the principal investigator and two trained research assistants who received prior training to ensure standardized administration and scoring procedures. The examiners responsible for outcome assessment were not involved in the delivery of the intervention program. All instructions were delivered in Arabic to ensure full comprehension by the participating children. Before the formal assessment, brief practice trials were provided in accordance with the standard administration protocol.

All stages of the HTKS-R task were administered following the procedures described in [15]. Children's responses were recorded during testing using a standardized scoring sheet. Each item was scored using a standard three-point system (0 = incorrect response, 1 = self-corrected response, 2 = correct response). Total scores ranged from 0 to 118, with higher scores indicating better executive function and behavioral self-regulation performance. The average administration time was approximately 5–6 minutes per child.

The HTKS-R has demonstrated reliability and validity as a measure of executive function and behavioral self-regulation in young children and has been widely used in developmental and educational research [14,15]. The task has also been applied in educational research conducted in Iraq, supporting its applicability within similar cultural and educational contexts [16].

Motor Coordination (KTK)

Motor coordination was measured using the Körperkoordinationstest für Kinder (KTK), a standardized test for assessing gross motor coordination in children aged 5 to 14 years [17]. The KTK consists of four subtests that measure different aspects of motor coordination: Walking Backward (WB), Hopping for Height (HH), Jumping Sideways (JS), and Moving Sideways (MS).

In the Walking Backward subtest, children walked backward along three beams of different widths (6, 4.5, and 3 cm), and the total number of successful steps was recorded. In the Hopping for Height subtest, participants hopped over a foam obstacle with progressively increasing height, and points were awarded for each successful attempt. In the Jumping Sideways subtest, participants performed as many lateral jumps as possible over a beam within 15 seconds, and the total number of successful jumps was recorded. In the Moving Sideways subtest, participants moved sideways between two wooden platforms, and the total number of successful relocations was recorded.

The KTK has demonstrated reliability and validity for assessing motor coordination in children. Previous studies have reported high reliability coefficients and acceptable construct validity for this test battery [18,19]. In the present study, the KTK was administered according to standardized procedures described in the KTK protocol, and the research team ensured consistent implementation during data collection.

Consistent with several intervention studies, the four KTK subtests were analyzed individually rather than using the overall Motor Quotient (MQ). This approach allows a more detailed examination of specific components of motor coordination and helps identify which motor skills are most responsive to the intervention.

Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics version 26 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for all study variables and are presented as mean ± standard deviation (SD).

The study employed a cluster randomized design in which schools served as the unit of randomization, while outcome measurements were obtained at the individual student level. Because students were nested within schools, the hierarchical structure of the data was considered in the analysis. Cluster-randomized studies require analytical approaches that account for intra-cluster correlation among participants within the same cluster to avoid biased statistical inference [20].

Intraclass correlation coefficients (ICCs) were calculated to quantify the proportion of variance attributable to clustering at the school level. The ICC values indicated moderate clustering for executive function (HTKS-R) and relatively low clustering for motor coordination outcomes.

Because the number of clusters was relatively small, cluster-level mixed-effects models may produce unstable variance estimates. Given the cluster-randomized design and the small number of clusters (eight schools), baseline-adjusted linear regression models with cluster-robust standard errors at the school level were used to estimate intervention effects. In each model, the post-intervention score was entered as the dependent variable, the group (coded as 1 = experimental and 0 = control) was included as the primary predictor, and the corresponding pre-intervention score was included as a covariate to control for baseline performance.

Regression analyses were performed separately for each outcome, including HTKS-R, Walking Backward, Hopping for Height, Jumping Sideways, and Moving Sideways. Regression coefficients (β), standard errors (SE), 95% confidence intervals (CI), and p-values were reported. A p-value of less than 0.05 was considered statistically significant.

Model assumptions were examined prior to analysis. Residual diagnostics indicated no substantial violations of normality or homoscedasticity.

A post hoc statistical power analysis was conducted using G*Power 3.1 to evaluate whether the final sample size provided sufficient statistical power to detect meaningful intervention effects. Based on the final sample of 304 participants (152 per group) and the observed effect sizes, the study achieved statistical power of approximately 0.96 at an alpha level of 0.05, indicating that the sample size was adequate to detect meaningful differences between groups [21].

Missing data were minimal. Fifteen participants were lost to follow-up during the intervention period due to prolonged absence, school transfer, or failure to complete the post-intervention assessment. Because the proportion of missing data was small (less than 5% of the baseline sample), a complete-case analysis approach was applied. This approach can provide valid results when missing data are minimal or occur completely at random [22]. Therefore, all analyses were conducted using data from the 304 participants who completed both pre- and post-intervention assessments.

Because executive function (HTKS-R) was defined as the primary outcome and motor coordination variables derived from the KTK test were considered secondary outcomes, no formal adjustment for multiple comparisons was applied. Instead, results for secondary outcomes were interpreted cautiously in the context of the overall pattern of findings.

Results

To assess the degree of clustering at the school level, intraclass correlation coefficients (ICCs) were estimated. The ICC value for HTKS-R indicated moderate clustering at the school level (ICC = 0.19), whereas ICC values for motor coordination outcomes were low (range: 0.00–0.07).

Baseline characteristics of participants in the experimental and control groups are presented in Table 1. Independent samples t-tests were conducted to examine baseline differences between the experimental and control groups. No statistically significant differences were observed for age, HTKS-R, Walking Backward, Jumping Sideways, or Moving Sideways ($p > 0.05$). A small difference was observed for Hopping for Height at baseline ($p = 0.039$). However, baseline-adjusted regression models were used in the primary analyses to account for any initial group differences.

Descriptive statistics for HTKS-R and the KTK subtests at the pre- and post-intervention assessments are presented in Table 2. At the pre-intervention stage, the experimental and control groups showed comparable mean scores across all measures. Post-intervention values were generally higher in the experimental group for HTKS-R and several KTK subtests compared with the control group.

Post-intervention HTKS-R scores were analyzed using baseline-adjusted linear regression models with cluster-robust standard errors at the school level to account for the clustered structure of the data. Group was entered as the main predictor, and the corresponding pre-intervention HTKS-R score was included as a covariate. The results of the model are presented in Table 3.

Post-intervention KTK outcomes were analyzed using baseline-adjusted linear regression models with cluster-robust standard errors at the school level. For each KTK subtest, group was entered as the main predictor, and the corresponding pre-intervention score was included as a covariate. The results for Walking Backward, Hopping for Height, Jumping Sideways, and Moving Sideways are presented in Table 4.

The baseline-adjusted regression analyses (Table 4) showed that, after accounting for school-level clustering and baseline performance, the experimental group achieved significantly higher post-intervention scores than the control group in Walking Backward ($\beta = 1.987$, 95% CI [1.031, 2.942], $p = .002$), Jumping Sideways ($\beta = 0.502$, 95% CI [0.156, 0.848], $p = .011$), and Moving Sideways ($\beta = 1.282$, 95% CI [0.871, 1.693], $p < .001$). In contrast, the between-group difference for Hopping for Height was not statistically significant ($\beta = 0.952$, 95% CI [-0.652, 2.557], $p = .203$).

Overall, the baseline-adjusted regression analyses (Tables 3 and 4) indicated that participation in the rule-reversal ball games program was associated with higher post-intervention executive function scores, as measured by HTKS-R, compared with the control condition. For motor coordination outcomes, the experimental group demonstrated higher post-intervention scores in Walking Backward, Jumping Sideways, and Moving Sideways after accounting for baseline performance and clustering by school, whereas no statistically significant between-group difference was observed for Hopping for Height. These findings provide an empirical description of the differential responsiveness of specific motor coordination components to the intervention.

Table 1. Baseline characteristics of participants in the experimental and control groups

Variable	Experimental (n = 152) Mean ± SD	Control (n = 152) Mean ± SD	p-value
Age (months)	75.91 ± 3.00	75.91 ± 3.11	0.985
HTKS-R (pre)	53.63 ± 4.05	53.98 ± 4.10	0.456
Walking Backward (pre)	30.32 ± 4.84	29.79 ± 4.90	0.341
Hopping for Height (pre)	25.68 ± 4.21	26.70 ± 4.42	0.039
Jumping Sideways (pre)	36.75 ± 3.56	36.80 ± 3.29	0.894
Moving Sideways (pre)	28.08 ± 3.90	27.57 ± 3.86	0.256

Note. Values are presented as mean ± standard deviation (SD). HTKS-R = Head-Toes-Knees-Shoulders Revised. Baseline differences between groups were examined using independent samples t-tests.

Table 2. Pre- and post-intervention descriptive statistics for HTKS-R and KTK outcomes

Variable	Experimental Pre (Mean ± SD)	Experimental Post (Mean ± SD)	Control Pre (Mean ± SD)	Control Post (Mean ± SD)
HTKS-R	53.63 ± 4.05	57.65 ± 4.04	53.98 ± 4.10	53.96 ± 4.01
Walking Backward	30.32 ± 4.84	32.19 ± 4.99	29.79 ± 4.90	29.72 ± 4.80
Hopping for Height	25.68 ± 4.21	26.62 ± 4.50	26.70 ± 4.42	26.59 ± 4.15
Jumping Sideways	36.75 ± 3.56	37.03 ± 3.60	36.80 ± 3.29	36.58 ± 3.60
Moving Sideways	28.08 ± 3.90	29.33 ± 4.37	27.57 ± 3.86	27.55 ± 3.92

Note. Values are presented as mean ± SD. HTKS-R = Head-Toes-Knees-Shoulders Revised; KTK = Körperkoordinationstest für Kinder; WB = Walking Backward; HH = Hopping for Height; JS = Jumping Sideways; MS = Moving Sideways.

Table 3. Baseline-adjusted regression results for post-intervention HTKS-R

Predictor	Estimate (β)	SE	95% CI	p	Effect size (Cohen's d)
Group (Experimental vs Control)	4.021	0.143	3.682 to 4.360	< .001	0.92
HTKS-R pre-test	0.947	0.022	0.895 to 0.999	< .001	—

Note. Baseline-adjusted linear regression with cluster-robust standard errors at the school level. Group was coded as 1 = experimental and 0 = control. HTKS-R = Head-Toes-Knees-Shoulders Revised; SE = standard error; CI = confidence interval. Cohen's d represents the standardized effect size calculated from post-intervention group differences using pooled standard deviations.

Table 4. Baseline-adjusted regression results for post-intervention KTK outcomes

Outcome	Predictor	Estimate (β)	SE	95% CI	p	Effect size (Cohen's d)
Walking Backward	Group (Experimental vs Control)	1.987	0.404	1.031 to 2.942	.002	0.50
	Walking Backward pre-test	0.914	0.043	0.811 to 1.017	< .001	—
Hopping for Height	Group (Experimental vs Control)	0.952	0.678	-0.652 to 2.557	.203	0.01
	Hopping for Height pre-test	0.896	0.017	0.855 to 0.936	< .001	—
Jumping Sideways	Group (Experimental vs Control)	0.502	0.146	0.156 to 0.848	.011	0.13
	Jumping Sideways pre-test	0.914	0.052	0.791 to 1.036	< .001	—
Moving Sideways	Group (Experimental vs Control)	1.282	0.174	0.871 to 1.693	< .001	0.43
	Moving Sideways pre-test	0.975	0.020	0.928 to 1.023	< .001	—

Note. Baseline-adjusted linear regression models with cluster-robust standard errors at the school level were fitted separately for each KTK subtest. Group was coded as 1 = experimental and 0 = control. SE = standard error; CI = confidence interval. Cohen's d represents standardized effect sizes calculated from post-intervention group differences using pooled standard deviations.

Discussion

In this study, the effects of rule-reversal ball games on executive function and motor coordination were analyzed among first-grade boys participating in a cluster randomized controlled trial. The findings indicate that participants in the rule-reversal ball games program demonstrated significantly higher post-intervention HTKS-R scores compared with the control group. Incorporating cognitively demanding components into physical activity may support the development of executive functioning abilities. Integrating cognitive demands within motor activity provides opportunities for developing these skills in young children.

During the intervention, children were required to perform goal-directed motor actions while applying opposite rules, which likely engaged multiple components of executive function simultaneously, including working memory, inhibitory control, and cognitive flexibility. The results are consistent with evidence indicating that early childhood is a sensitive period for the development of executive function skills. Successful performance on the HTKS-R task requires multiple cognitive processes that are responsive to cognitively enriched movement activities in early childhood [23, 24].

The structure of the rule-reversal paradigm used in the intervention parallels the inhibitory control demands of the HTKS-R task, which may partly explain the observed improvements in executive function performance. The improvement may also reflect a near transfer effect, as both the intervention and the HTKS-R assessment involve rule reversal and response inhibition.

In addition to the observed changes in executive function, the findings indicate higher post-intervention motor coordination in the experimental group in Walking Backward, Jumping Sideways, and Moving Sideways. These results suggest that the rule-reversal ball games program may have influenced both cognitive processes and motor coordination. A key characteristic of the intervention was the use of continuously changing task conditions that required children to adapt their movements to different visual cues during locomotor and ball-handling activities. These conditions likely imposed additional demands on dynamic balance, bilateral coordination, and rapid movement adjustment during task execution, which correspond to the requirements of several KTK subtests, particularly those involving balance and lateral coordination.

Studies indicate that physical activity combined with cognitive challenges engages both cognitive processes and motor coordination, as children must continuously adjust their movements in response to changing task constraints [25]. In this context, the rule-reversal tasks implemented in the intervention may have created a cognitively enriched movement environment associated with KTK-related motor components, contributing to coordination performance. These interpretations should be considered in relation to the specific motor demands of the activities used in the intervention.

Because multiple motor coordination outcomes were analyzed separately, the findings should be interpreted with caution due to the increased risk of type I error.

While improvements were observed in several coordination-related subtests, no statistically significant difference between the experimental and control groups was found for the Hopping for Height subtest of the KTK. This result may be explained by the specific motor demands of this subtest. Hopping for Height requires repeated single-leg jumps over progressively higher obstacles, reflecting both coordination and lower limb explosive strength.

In contrast, other KTK subtests, including Walking Backward, Jumping Sideways, and Moving Sideways, place greater emphasis on dynamic balance and rapid coordination adjustments during continuous movement. The motor tasks included in the rule-reversal ball games program primarily focused on balance regulation, responses to visual cues, and adaptation to changes in body position during movement. As a result, the intervention may not have provided sufficient stimulus to improve performance in tasks that depend more on muscular power.

Previous studies indicate that different components of motor competence respond differently to intervention programs depending on the specific characteristics of the training [26]. The KTK battery includes subtests that assess related but distinct motor abilities, which may show differential responsiveness depending on the type of intervention applied [19, 27].

HTKS-R performance improved, indicating that the development of executive functioning skills may benefit from physically active, cognitively engaging activities. Studies indicate that children who participate in such activities, including those requiring rule switching, inhibition of impulsive responses, and performance monitoring, demonstrate improvements in executive function processes. In addition, inhibitory control appears to be particularly responsive to cognitively stimulating movement activities. These findings suggest that incorporating cognitive demands into physical activity may enhance executive function by requiring children to continuously monitor task instructions and adjust their behavior during performance [10, 11].

Many recent studies support the current findings concerning the role of physical activity (PA) interventions with cognitive demands in the development of executive functioning in children. In recent systematic reviews and meta-analyses, Wang reported that cognitively engaging physical activity is associated with significant improvements in core executive functions during childhood. For example, studies indicate that PA interventions structured to include cognitive challenges alongside movement tasks lead to improvements in inhibitory control and working memory, two domains of executive function that are responsive to cognitive engagement within PA programs [10].

Meta-analyses also suggest that PA interventions incorporating cognitive components result in greater improvements in executive function compared with traditional motor-based physical education [28]. In addition, recent reviews indicate that repeated engagement in cognitive control processes during structured movement activities may contribute to improvements in executive functioning, as children are required to continuously adjust their behavior in response to changing task demands [29]. The rule-reversal ball games used in the present study represent an approach that integrates cognitive challenges into physical activity, providing conditions for the simultaneous engagement of executive functions and motor coordination during physical education classes.

The present study indicates that incorporating cognitively enriched movement activities into regular physical education programs in early school years may support both cognitive and motor development in children. The inclusion of simple cognitive challenges, such as rule reversals and response adaptation, appears feasible within standard physical education lessons and may contribute to the development of both executive function and motor skills.

This study contributes to existing research on cognitively enriched physical activity by providing empirical data on both cognitive and selected motor outcomes associated with a rule-reversal ball game intervention implemented within regular physical education programs. The cluster-randomized design and school-based implementation strengthen the ecological validity of the findings, as the intervention was conducted during regular physical education lessons in a natural school setting.

The analytical approach was based on baseline-adjusted regression models. While this approach provides valid estimates of post-intervention group differences, alternative modeling strategies, such as models including group × time interaction terms, may offer additional information on changes over time. The main conclusions are unlikely to be substantially affected by the choice of model specification.

Limitations of the Study and Future Research Directions

Several limitations should be considered when interpreting the results of this study. The sample included only first-grade boys attending private schools in one city, which may limit generalizability. The intervention duration was limited to eight weeks, and therefore the sustainability of the observed effects cannot be determined. In addition, the relatively small number of clusters (schools) may reduce the precision of cluster-adjusted estimates, and the findings should be interpreted with caution.

Future research should examine cognitively enriched physical activity programs across different age groups, school settings, and populations, including girls. Longer intervention periods and follow-up assessments may provide additional insight into the effects of such programs on executive function and motor development over time.

Conclusions

The study found that implementing a rule-reversal ball games program as part of regular physical education lessons was associated with improvements in executive function in boys aged 6–7 years. The inclusion of simple cognitive challenges within physical activity may support the development of executive functioning skills in young children. The program was also associated with improvements in several components of motor coordination, particularly those related to balance and coordinated lateral movements. However, not all aspects of motor coordination were affected, suggesting that some motor abilities may require different or additional types of training stimuli for improvement. Incorporating cognitively enriched movement activities into school physical education may provide a practical approach to support both cognitive and motor development in early school-age children.

Conflict of interest

The authors declare no conflict of interest.

References

1. Miyake A, Friedman NP. The Nature and Organization of Individual Differences in Executive Functions: Four General Conclusions. *Current Directions in Psychological Science*, 2012;21(1): 8–14. https://doi.org/10.1177/0963721411429458
2. Blair C, Raver CC. School Readiness and Self-Regulation: A Developmental Psychobiological Approach. *Annual Review of Psychology*, 2015;66(1): 711–731. https://doi.org/10.1146/annurev-psych-010814-015221
3. Zelazo PD, Blair CB, Willoughby MT. *Executive function: implications for education*. Washington (DC): National Center for Education Research, Institute of Education Sciences, U.S. Department of Education; 2016.
4. Bao R, Wade L, Leahy AA, Owen KB, Hillman CH, Jaakkola T, et al. Associations Between Motor Competence and Executive Functions in Children and Adolescents: A Systematic Review and Meta-analysis. *Sports Medicine*, 2024;54(8): 2141–2156. https://doi.org/10.1007/s40279-024-02040-1
5. Best JR. Effects of physical activity on children's executive function: Contributions of experimental research on aerobic exercise. *Developmental Review*, 2010;30(4): 331–351. https://doi.org/10.1016/j.dr.2010.08.001
6. Vasilopoulos F, Jeffrey H, Wu Y, Dumontheil I. Multi-Level Meta-Analysis of Physical Activity Interventions During Childhood: Effects of Physical Activity on Cognition and Academic Achievement. *Educational Psychology Review*, 2023;35(2): 59. https://doi.org/10.1007/s10648-023-09760-2
7. Schmidt M, Jäger K, Egger F, Roebers CM, Conzelmann A. Cognitively Engaging Chronic Physical Activity, But Not Aerobic Exercise, Affects Executive Functions in Primary School Children: A Group-Randomized Controlled Trial. *Journal of Sport and Exercise Psychology*, 2015;37(6): 575–591. https://doi.org/10.1123/jsep.2015-0069
8. Stodden DF, Goodway JD, Langendorfer SJ, Roberton MA, Rudisill ME, Garcia C, et al. A Developmental Perspective on the Role of Motor Skill Competence in Physical Activity: An Emergent Relationship. *Quest*, 2008;60(2): 290–306. https://doi.org/10.1080/00336297.2008.10483582
9. Diamond A. Close Interrelation of Motor Development and Cognitive Development and of the Cerebellum and Prefrontal Cortex. *Child Development*, 2000;71(1): 44–56. https://doi.org/10.1111/1467-8624.00117
10. Mao F, Huang F, Zhao S, Fang Q. Effects of cognitively engaging physical activity interventions on executive function in children and adolescents: a systematic review and meta-analysis. *Frontiers in Psychology*, 2024;15: 1454447. https://doi.org/10.3389/fpsyg.2024.1454447
11. Bulten R, Bedard C, Graham JD, Cairney J. Effect of cognitively engaging physical activity on executive functions in children. *Frontiers in Psychology*, 2022;13: 841192. https://doi.org/10.3389/fpsyg.2022.841192
12. Liu S, Chen ST, Cai Y. Associations Between Gross Motor Coordination and Executive Functions: Considering the Sex Difference in Chinese Middle-Aged School Children. *Frontiers in Psychology*, 2022;13: 875256. https://doi.org/10.3389/fpsyg.2022.875256
13. Ibrahim A, Mohammed KJ, Mahdi AM, Mohammed TD, Jebur MS, Ghaeb YF. Stroop-based locomotor training improves executive attention and running in preschoolers. *Pedagogy of Physical Culture and Sports*, 2026;30(2):154–162. https://doi.org/10.15561/26649837.2026.0208
14. Gonzales CR, Bowles R, Geldhof GJ, Cameron CE, Tracy A, McClelland MM. The Head-Toes-Knees-Shoulders Revised (HTKS-R): Development and psychometric properties of a revision to reduce floor effects. *Early Childhood Research Quarterly*, 2021;56: 320–332. https://doi.org/10.1016/j.ecresq.2021.03.008
15. McClelland MM, Gonzales CR, Cameron CE, Geldhof GJ, Bowles RP, Nancarrow AF, et al. The Head-Toes-Knees-Shoulders Revised: Links to Academic Outcomes and Measures of EF in Young Children. *Frontiers in Psychology*, 2021;12: 721846. https://doi.org/10.3389/fpsyg.2021.721846
16. Ibrahim A, Jasim AG, Hawar AB, Ghaeb YF, Alsamarae MSK. Effect of HTKS-R–inspired visual reversal motor play on self-regulation and motor skills in preschoolers. *Retos*, 2025;73: 1145–1155. https://doi.org/10.47197/retos.v73.117771
17. Kiphard EJ, Schilling VF. *Körperkoordinationstest für Kinder (KTK): manual* [Body coordination test for children (KTK): manual]. Weinheim: Beltz Test; 1974. (In German).
18. Li K, Bao R, Kim H, Ma J, Song C, Chen S, et al. Reliability and validity of the Körperkoordinationstest Für Kinder in Chinese children. *PeerJ*, 2023;11: e15447. https://doi.org/10.7717/peerj.15447
19. Vandorpe B, Vandendriessche J, Lefevre J, Pion J, Vaeyens R, Matthys S, et al. The KörperkoordinationsTest für Kinder: reference values and suitability for 6–12-year-old children in Flanders. *Scandinavian Journal of Medicine*

& Science in Sports, 2011;21(3): 378–388. https://doi.org/10.1111/j.1600-0838.2009.01067.x

20. Tokolahi E, Hocking C, Kersten P, Vandal AC. Quality and Reporting of Cluster Randomized Controlled Trials Evaluating Occupational Therapy Interventions: A Systematic Review. *OTJR: Occupational Therapy Journal of Research*, 2016;36(1): 14–24. https://doi.org/10.1177/1539449215618625
21. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, 2007;39(2): 175–191. https://doi.org/10.3758/BF03193146
22. Heymans MW, Twisk JWR. Handling missing data in clinical research. *Journal of Clinical Epidemiology*, 2022;151: 185–188. https://doi.org/10.1016/j.jclinepi.2022.08.016
23. Kolovelonis A, Pesce C, Goudas M. The Effects of a Cognitively Challenging Physical Activity Intervention on School Children's Executive Functions and Motivational Regulations. *International Journal of Environmental Research and Public Health*, 2022;19(19): 12742. https://doi.org/10.3390/ijerph191912742
24. Schmidt M, Benzing V, Kamer M. Classroom-Based Physical Activity Breaks and Children's Attention: Cognitive Engagement Works! *Frontiers in Psychology*, 2016;7. https://doi.org/10.3389/fpsyg.2016.01474
25. Vazou S, Pesce C, Lakes K, Smiley-Oyen A. More than one road leads to Rome: A narrative review and meta-analysis of physical activity intervention effects on cognition in youth. *International Journal of Sport and Exercise Psychology*, 2019;17(2): 153–178. https://doi.org/10.1080/1612197X.2016.1223423
26. Robinson LE, Stodden DF, Barnett LM, Lopes VP, Logan SW, Rodrigues LP, et al. Motor Competence and its Effect on Positive Developmental Trajectories of Health. *Sports Medicine*, 2015;45(9): 1273–1284. https://doi.org/10.1007/s40279-015-0351-6
27. Cattuzzo MT, Dos Santos Henrique R, Ré AHN, De Oliveira IS, Melo BM, De Sousa Moura M, et al. Motor competence and health related physical fitness in youth: A systematic review. *Journal of Science and Medicine in Sport*, 2016;19(2): 123–129. https://doi.org/10.1016/j.jsams.2014.12.004
28. Song Y, Fan B, Wang C, Yu H. Meta-analysis of the effects of physical activity on executive function in children and adolescents with attention deficit hyperactivity disorder. Jan YK (ed.) *PLOS ONE*, 2023;18(8): e0289732. https://doi.org/10.1371/journal.pone.0289732
29. Guzmán-Muñoz E, Concha-Cisternas Y, Jofré-Saldía E, Castillo-Paredes A, Molina-Márquez I, Yáñez-Sepúlveda R. Physical Activity and Its Effects on Executive Functions and Brain Outcomes in Children: A Narrative Review. *Brain Sciences*, 2025;15(11): 1238. https://doi.org/10.3390/brainsci15111238

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