DOI 10.26773/smj.250602

ORIGINAL SCIENTIFIC PAPER

Cognitive and Physical Development in Childhood: A Study of Visual-Motor Coordination and Fitness in Kyrgyzstan

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Abstract

This study examines the relationship between cognitive performance, particularly visual-motor coordination, and physical fitness among 3345 children aged 8 to 10 from Kyrgyzstan's Bishkek and Chüy regions. The primary objective was to explore how visual-motor coordination and decision-making skills relate to physical performance in middle childhood. Physical fitness was assessed using the Eurofit test battery, which evaluates general physical competence across multiple components such as strength, balance, and flexibility, and is widely used in developmental and educational settings. The Kohs Block Design Test (KOHS) evaluated cognitive performance, particularly visual-motor coordination. Correlation analysis was performed to examine the relationship between physical performance and visual-motor coordination. Data analysis also involved the Shapiro–Wilk test for normality, one-way ANOVA and Tukey's post hoc tests for age group comparisons, and independent t-tests for gender differences. All statistical analyses were performed using SPSS Version 21, with significance set at $p<0.05$. Eight-year-olds demonstrated significantly better visual-motor coordination compared to 9- and 10-year-olds ($p<0.01$), and 8-year-old girls outperformed boys ($p<0.05$). A strong negative correlation was found, indicating that faster completion times in visual-motor tasks were associated with better physical performance. Additionally, physical performance scores generally improved with age. The findings highlight a strong association between visual-motor coordination and physical performance. The findings highlight a strong association between visual-motor coordination and physical performance, supporting the notion that these abilities develop in parallel during early childhood. This underscores the importance of early interventions that target both cognitive-perceptual and motor domains to foster well-rounded developmental progress.

Keywords: *visual-motor coordination, physical performance, physical fitness, cognitive performance*

Introduction

Middle childhood, encompassing ages 8 to 10, is a period marked by a rapid transition through specific developmental sequences and stages (Aral & Baran, 2011; Bacanlı, 2001). The shift from concrete to abstract thinking typically begins around the age of 6 or 7 and continues until approximately 11 or 12 years of age (Yazgan et al., 2004). During this phase, children's cognitive development advances, enabling them to perform more complex tasks, use language more effectively, extend their attention spans, and enhance their memory utilization (Gander & Gardiner, 2001). They begin to focus less on the superficial features of objects and pay greater attention to underlying causes, emphasizing the realities beneath appearances (Shaffer, 1996). This cognitive development becomes evident not only

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in their understanding of objects but also in their perceptions of others, relationships, and themselves (Aral & Baran, 2011).

In addition to cognitive development, self-perception and self-concept evolve as children assume new roles beyond the family, particularly with the introduction of school life (Bayhan & Artan, 2009). This period also marks early pubertal changes in girls and significant advancements in motor skills, including increased muscle strength and coordination, enhancing abilities such as running, jumping, and throwing (Yazgan et al., 2004).

In line with the focus of this study, only cognitive development aspects closely related to physical performance are emphasized. Rather than detailing general intelligence theories or broad psychometric approaches, this introduction concentrates on functional cognitive skills such as visual-motor coordination.

Cognitive development arises from the interaction between biological maturation and environmental experiences (Carey et al., 2015). According to Piaget, this development is a dynamic process characterized by a continual cycle of equilibrium, disequilibrium, and re-equilibration, in which individuals adapt to new stimuli to function effectively. His theory describes a progression through four developmental stages: in the sensorimotor stage, which spans from birth to approximately two years of age, infants learn about the world through sensory and motor interactions. This is followed by the preoperational stage, from ages two to seven, during which symbolic thinking begins to emerge, although logical reasoning remains limited. Between the ages of seven and eleven, children enter the concrete operational stage, where logical thinking becomes more pronounced but is still grounded in tangible, concrete experiences. Finally, in the formal operational stage, beginning around age eleven, individuals acquire the ability to think abstractly and reason about hypothetical situations (Lourenço, 2016).

The study group in this research corresponds to the concrete operational stage, during which children begin to overcome egocentrism and consider others' perspectives, even though their reasoning remains bound to observable and tangible situations (Oesterdiekhoff, 2016). At this stage, thinking becomes more flexible; children develop the ability to understand cause-effect relationships, classify and arrange objects according to certain attributes, and comprehend fundamental logical principles such as conservation and reversibility. While cognitive differences between boys and girls are generally minimal, girls tend to exhibit faster physical development up to approximately age 11, after which boys demonstrate accelerated growth (Yazgan et al., 2004).

In the context of this research, visual-motor coordination is particularly significant due to its role in both cognitive functioning and physical performance. Skills such as spatial orientation, motor planning, and sensorimotor integration are directly relevant to children's ability to perform physically demanding tasks. This provides a scientifically grounded framework for understanding how cognitive and motor domains interact in middle childhood.

Recent research supports the critical role of visual-motor coordination in academic success, daily functioning, and sport performance. For instance, visual-motor integration is strongly linked with early literacy and numeracy skills (Cameron et al., 2012). Additionally, studies show that motor coordination enhances attention and memory, and that sensorimotor interventions can improve cognitive and social skills in children (Roebers & Kauer, 2009). These findings reinforce the value of integrating visual-motor skill development in both educational and sport-related practices.

Considering this information, the aim of this study is to examine cognitive development in children aged 8 to 10 in relation to physical performance and to identify age and gender related cognitive differences.

Methods

Research design

This study was conducted under the protocol signed between Kyrgyz-Turkish Manas University, the Ministry of Education and Science of the Kyrgyz Republic, and the Ministry of Sports of the Kyrgyz Republic. It involved the assessment of physical performance in a total of 3,345 children attending 17 public schools in the Bishkek and Chüy regions of Kyrgyzstan. The children were divided into three age groups: 8 years old (girls: 616, boys: 612), 9 years old (girls: 631, boys: 586), and 10 years old (girls: 419, boys: 481). In this study, children who showed superior results in standardized physical fitness tests were noted. Additionally, their cognitive performance in quick and accurate decision-making was measured, and the relationship between physical and cognitive performance was examined.

The study protocol was approved by the Ethics Committee of the Kyrgyz State University of Physical Education (Approval No.1382018) and conducted in full compliance with the principles outlined in the Declaration of Helsinki.

Determination of physical performance

To evaluate students' physical performance, the Eurofit Test Battery was used. The Eurofit Test Battery assesses balance, flexibility, upper body strength, explosive leg power, reaction speed, abdominal endurance, aerobic capacity, and agility with coordination. This test battery has been endorsed by the Committee of Ministers of the Council of Europe as a standardized tool for assessing the physical fitness of children aged 6–18 years (Adam et al., 1988). Before the tests, all children in the study were informed about the test procedures and measurement tools in both Kyrgyz and Russian. Practical demonstrations were also provided to familiarize participants with the process. Each student underwent a health evaluation by medical professionals before testing, and only those who received medical clearance were allowed to participate. Doctors and nurses remained on-site throughout the measurement process to ensure the safety of the participants.

Visual-Motor Coordination Test

This timed assessment comprises 17 cards and patterned blocks. Participants were seated at a table and shown the completed version of the test for 20 seconds. Subsequently, they were instructed to replicate the displayed pattern by rearranging the scattered blocks within a 2-minute time limit. The time taken to complete the task was recorded as the score. Participants who were unable to complete the task within the allotted time were assigned a score of zero.

In addition to the tests administered to evaluate physical performance, the Kohs Block Design Test (KOHS) was used to assess children's visual-motor coordination. This non-verbal test is validated for children aged six and above and is widely applied in linguistically diverse populations due to its language-free structure (Kaufman & Lichtenberger, 2006; Sattler, 2001). Incorporated into standard intelligence batteries, KOHS is supported by studies reporting strong internal consistency and test–retest reliability (Lezak et al., 2012).

In this study, participants were shown a model pattern and asked to reconstruct it using colored blocks within a two-minute time limit. The completion time was recorded as a measure of visual-motor coordination, with shorter durations indicating better performance. KOHS results were then analyzed in relation to the children's physical performance scores to explore cognitive–motor interaction.

Statistical analysis

The data were analyzed using an index method, where the test scores of the children were equally weighted and calculated through a specially designed program in Excel. The Visual-Motor Coordination Test (Kohs Block Design Test - KOHS) was used to assess visual-motor coordination and quick, accurate decision-making skills. The scores from this test were combined with the physical measurements obtained through the Eurofit test battery to create a comprehensive performance index. Each parameter was weighted and normalized to ensure equitable comparisons among participants.

Data analysis was conducted using IBM SPSS Statistics 21. The Shapiro-Wilk test assessed normality. One-way ANOVA with Tukey post-hoc compared age groups (8, 9, 10 years), and independent t-tests analyzed gender differences. Pearson's or Spearman's correlation evaluated relationships between Visual-Motor Coordination and physical test scores. A 95% confidence interval was used, with $p<0.05$ considered statistically significant.

Results

The demographic characteristics of the participants, including height and body weight, categorized by age groups for both boys and girls, are presented in Table 1.

Table 1. Descriptive Statistics of Participants by Age Groups

Gender	Age	n	Height (cm)	Weight (kg)
Girls (n:1666)	8	616	127.26±5.65	26.88±4.85
	9	631	132.80±5.94	29.88±5.73
	10	419	137.94±6.60	32.85±6.84
Boys (n:1679)	8	612	128.17±6.78	27.85±5.39
	9	586	133.49±6.14	30,72±6.53
	10	481	138.25±6.00	33.69±6.72

As illustrated in Table 2, a reduction in the completion time of the intelligence test was associated with an increase in the performance scores from the physical performance tests. A strong negative correlation was observed between intelligence test completion times and physical test performance scores.

Table 3 presents a combined evaluation of test results for boys and girls, showing that as age increased, average test scores decreased while completion times improved.

Table 2. Relationship Between Visual-Motor Coordination Test Scores and Physical Test Scores

	All participants	Girls	Boys	Age 8	Age 9	Age 10
N	3345	1666	1679	1228	1217	900
Correlations	-0.258	-0.273	-0.285	-0.267	-0.254	-0.222
P	0.001	0.001	0.001	0.001	0.001	0.001

Note (0-0.10- Weak), (0.10-0.20 - moderate), (0.20 and above - strong or powerful); A negative (-) sign indicates that as one value increases, the other decreases, demonstrating an inverse relationship.

Table 3. Visual-Motor Coordination and Physical Test Results by Age Groups

Tests	Age 8	Age 9	Age 10	Total
	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Flamingo Balance Test	13.83±0.58 †	12.11±0.49 ‡	11.05±0.45 ‡	12.46±0.3
Plate Tapping Test	18.95±0.09 †	17.35±0.08 ‡	16.18±0.09 §	17.62±0.06
Standing Broad Jump	116.59±0.50 §	125.54±0.54 ‡	133.39±0.6 †	124.37±0.33
10x5 Meter Shuttle Run	24.32±0.07 †	23.45±0.07 ‡	22.78±0.11 ‡	23.59±0.05
Handgrip Strength Test (Right)	13.94±0.09 §	15.69±0.1 ‡	17.49±0.13 †	15.53±0.07
Handgrip Strength Test (Left)	13.46±0.09 §	15.01±0.09 ‡	16.75±0.12 †	14.91±0.06
Sit-Up Test	15.58±0.25 †	15.80±0.2 †	16.00±0.22 ‡	15.77±0.13
Bent Arm Hang	12.39±0.42 †	12.18±0.4 †	11.18±0.41 ‡	11.99±0.24
Sprint (20 m)	4.87±0.01 †	4.67±0.01 ‡	4.49±0.01 §	4.70±0.01
Sit and Reach Test	27.21±0.17 †	2.81±0.17 †	27.74±0.19 †‡	27.68±0.1
Visual-Motor Coordination Test	1.74±0.03 †	1.59±0.03†	1.56±0.03†	1.64±0.02
N	1228	1217	900	3345

Note † ‡ §: Different symbols given in the same row indicate statistical significance.

The scores of 9- and 10-year-olds were statistically similar but significantly lower than those of 8-year-olds, indicating faster test completion among older children. In physical tests, the advancement in age was found to result in a statistically significant improvement in physical performance. Notably, 10-year-olds demonstrated the best scores across all parameters.

Table 4 examines the intelligence test results of boys and girls within the same age group. It was observed that 8-year-old girls scored significantly lower than boys on the intelligence test assessing fast and accurate decision-making. However, no statistically significant differences were detected between the intelligence test scores of boys and girls aged 9 and 10.

Table 4. Comparison of Visual-Motor Coordination Test Results Between Same-Age Girls and Boy

Variable	Age 8 Mean±SD	t	p	Age 9 Mean±SD	t	p	Age 10 Mean±SD	t	p
Girls	(1.70±0.04)	-1.449	0.031*	(1.51±0.04)	-3.137	0.527	(1.58±0.05)	0.744	0.793
Boys	(1.78±0.03)			(1.67±0.04)			(1.54±0.04)		
Total n=3345	Girls (n:616)			Girls (n:631)			Girls (n:419)		
	Boys (n: 612)			Boys (n:586)			Boys (n:481)		

Note $^{*}p<0.05$; $^{**}p<0.01$

Discussion

This study investigates the relationship between physical performance and cognitive abilities, particularly visual-motor coordination, and it focuses on developmental characteristics that influence both motor and cognitive skills. The KOHS blocks were selected to assess both concrete and abstract thinking skills. The literature highlights the strong link between visual-motor coordination and cognitive abilities such as decision-making, attention, and hand-eye coordination. In this context, understanding the interaction between physical performance and visual-motor skills contributes to clarifying developmental dynamics during middle childhood.

The analysis of Table 3 indicates that the time-based performance of the 8-year-old group, assessed using KOHS blocks, was recorded as 1.74, decreasing by 15 seconds to 1.59 in the 9-year-old group. Although the time continued to decrease in the 10-year-old group, the difference between the 9- and 10-year-olds was only three seconds. Statistical analysis revealed a significant difference between the 8-year-old group and both the 9- and 10-year-old groups, whereas the difference between the 9- and 10-year-old groups was not statistically significant. These findings are consistent with the developmental psychology literature.

The period between 8 and 11 years is a crucial stage in human development, often termed 'early adolescence' (Shaffer, 1996) or 'pre-adolescence' (Çapri & Çelikkaleli, 2005). During this phase, physical, emotional, cognitive, and sexual development accelerate, with girls typically entering earlier than boys (Gander & Gardiner, 2001). The timing of this stage is influenced by climate, culture, nutrition, and environmental factors (Bertan et al., 2009), alongside significant individual differences in development.

From age 8, girls, followed by boys a year or two later, show significant improvements in hand-eye coordination, enhancing tool-handling skills (Boyd & Bee, 2009). This period also marks increased cognitive development, enabling children to establish cause-and-effect relationships (Kandemir, 2007; Wood, 1998) and engage in tasks beyond their physical capacity (Bingham, 1983; Özer & Özer, 2005). While concrete operational thinking remains dominant, abstract reasoning improves, allowing them to recognize connections between geometric shapes, events, and objects (Wadsworth, 2015). The use of KOHS blocks in this study aligns with these cognitive developments.

Children in this age group exhibit a highly developed imagination, a strong sense of autonomy, and a tendency to act independently (Nicolopovlov, 1993). Additionally, a significant increase in self-confidence is observed during this developmental stage (Gallahue & Ozmun, 1998).

The acceleration in cognitive development typically becomes evident around the age of 8 and maintains similar characteristics until the age of 12; however, the initial pace does not continue at the same rate in the following years (Charlesworth, 2004). While 8-year-old children are at a beginner level in discovering numerical concepts, relationships, and processes, there is a notable improvement in these skills as they approach the age of 9 (Charlesworth, 2004; Gander & Gardiner, 2001). As shown in Table 4, the significant time difference between the 8 and 9-10 age groups supports this observation. By the age of 9, children's problem-solving skills have significantly improved; however, it cannot be said that they have fully reached the stage of abstract thinking (Nicolopoulou, 2004). The 8-year-old group mainly exhibits characteristics of concrete cognitive development, showing a tendency to reason based on tangible objects. However, as they approach the age of 9, this process gradually evolves towards abstract thinking.

KOHS blocks were chosen as an effective tool for assessing both concrete and abstract thinking skills and distinguishing the performance of the 8-10 age group sample (Boake, 2002). The significant difference observed between the 8 and 9-10 age groups indicates that the method possesses sufficient discriminative power. Children's ability to perceive the whole, understand how its parts can be interchanged, and integrate them to solve a problem reflects both concrete and abstract intelligence (Kunda et al., 2016).

The correlation values presented in Table 2 further support this finding. In the measurements conducted on 3,345 children using KOHS blocks, it was observed that as the allotted time decreased, performance scores in physical performance tests increased (r=-0.258, p<0.001). This indicates a moderate negative correlation between time and performance. Spending less time on comprehension, understanding, discovery, decision-making, and execution is an indicator of higher cognitive functioning (Burggraaf et al., 2018). The consistency of results across all age groups confirms the reliability of these measurements.

Although research on the interaction between cognitive and motor development remains limited, the present study contributes to the field by examining how cognitive skills, particularly visual-motor coordination, relate to age-related developmental changes in physical performance. These findings should be interpreted within a developmental context. The observed relationship supports the idea that enhancing cognitive functions may indirectly contribute to improved physical skills in educational and developmental programs.

These findings have practical implications beyond research. Integrating visual-motor coordination assessments into early childhood education programs can support both cognitive and physical development. Additionally, such tools can be employed in school-based screening to identify children who may benefit from early interventions aimed at improving attention, decision-making, and motor planning. This developmental approach could enhance the effectiveness of curricula in physical education and general cognitive readiness (Brian et al., 2017; Robinson et al., 2015).

Gender differences align with cognitive development theories. As shown in Tables 1 and 4, the average performance time for 8-year-old girls is 1.7 seconds, compared to 1.78 seconds for boys. This difference can be attributed to girls entering puberty earlier, allowing them to transition to abstract thinking 1–2 years before boys (Özer & Özer, 2005). This advantage in KOHS block performance persists at ages 9 and 10. While the 0.08-second gap between boys and girls at age 8 is minimal, it increases to 0.16 seconds by age 9, doubling in size. This progression highlights the differing cognitive development rates between genders.

Another indication of the alignment between measurements and cognitive development theories is the decreasing difference between boys and girls at age 10 compared to age 9. As shown in Table 4, the performance time for 10-year-old girls (1.58 seconds) closely matches that of boys (1.54 seconds). This suggests that while boys enter puberty later, their accelerated development narrows the gap over time (Gander & Gardiner, 2001; Kandemir, 2007). Across the 8-10 age range, the difference remains in favor of girls by 0.07 seconds, and it is expected to diminish beyond age 10.

Our findings highlight visual-motor coordination as a key predictor of physical performance, particularly at younger ages, though varying by age and gender. Table 2 shows a significant inverse relationship between visual-motor coordination and physical performance ($r=-0.258$, $p<0.001$), indicating that better coordination (lower completion time) correlates with higher performance. Literature supports the critical role of visual-motor skills in cognitive and physical performance. Robinson et al. (2015) emphasize their role in motor competence development, especially in early childhood, where this relationship is strongest. They also suggest that the strength of motor-cognitive links may decrease with age, as developmental systems become more specialized.

Gender-specific analysis in this study shows a slightly stronger relationship in boys ($r=-0.285$) than in girls ($r=-0.273$), suggesting that cognitive skills may play a greater role in boys' motor performance development. Similar trends were reported in previous studies, indicating that gender may moderate the strength of motor-cognitive associations (Cameron et al., 2012; Robinson et al., 2015).

Age-group analysis indicates the strongest relationship in 8-year-olds ($r=-0.267$), followed by 9-year-olds ($r=-0.254$) and 10-year-olds ($r=-0.222$), showing that visual-motor coordination has a greater impact on physical performance at younger ages, gradually decreasing with age. According to Piaget (1964), concrete operational thinking dominates during this stage, supporting visual-motor coordination, but reliance on these skills may decline as abstract thinking develops. These findings align with the literature, highlighting the importance of early interventions to enhance both cognitive and physical abilities.

Conclusion

The findings of this study underscore the strong connection between cognitive performance, particularly visual-motor coordination and decision-making speed, and physical performance. The results are fully consistent with the principles of developmental psychology and cognitive development theories. The emphasis should be placed on their relevance to cognitive and motor development in educational and health contexts. These findings can inform early interventions and educational practices aimed at improving children's cognitive and physical functioning in tandem.

Funding Statement

This study was supported by Kyrgyzstan Turkey Manas University and Turkish Cooperation and Coordination Agency (TIKA), Bishkek Coordination Office with protocol number BAP-71(5450).

Acknowledgments

We would like to express our gratitude to the staff of the State Agency for Physical Education and Sports of the Kyrgyz Republic, the Ministry of Education and Science of the Kyrgyz Republic, the Bishkek Metropolitan Municipality Education Department, and the Turkish Cooperation and Coordination Agency (TİKA) Bishkek Coordination Office for their support of this research.

Conflicts of Interest

All Authors declare that there is no conflict of interests regarding the paper and its publication.

Received: 24 February 2025 | **Accepted:** 24 May 2025 | **Published:** 01 June 2025

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