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Effects of Motor Cognitive and Metacognitive Interventions on Motor and Cognitive Skills of Preschool Children

* Fahimeh Rezaei [1], Hasan Mohammadzadeh [1], Behzad Behzadnia [2]

[1] Department of Motor Behavior, Faculty of Physical Education and Sport Sciences, Urmia University, Urmia, Iran.

[2] Department of Motor Behavior, Faculty of Physical Education and Sport Sciences, University of Tabriz, Tabriz, Iran.

Abstract

Background: Despite the growing body of research showing the effectiveness of motor interventions for children both physically and cognitively, there is still a lack of sufficient information regarding the effects of different motor programs and finding suitable interventions to improve motor and cognitive skills in early childhood. This study was conducted to investigate and compare the effects of cognitive and metacognitive factors in motor interventions on the motor and cognitive skills of preschool children.

Methods: Sixty-six 6-year-old children (32 girls, 34 boys) participated in this study and were randomly assigned to three experimental groups (motor group (7 girls, 10 boys), motor-cognitive group (8 girls, 8 boys), and motor-metacognitive group (7 girls, 9 boys)) along with a control group (10 girls, 7 boys). The participants in all three experimental groups received a motor program specific to their group for 18 sessions. The Bruininks-Oseretsky test of motor proficiency (BOT-2), the Toulouse-Pieron cancellation test (TP), and the Head-Toes-Knees-Shoulders task (HTKS) were used to collect data. Multivariate repeated measures and multivariate analysis of covariance were used for data analysis.

Results: The findings showed that, compared to the control group, the improvement of cognitive skills in the motor-cognitive group was more than that in the motor and motor-metacognitive groups ($p < 0.05$). Also, the improvement of motor skills in the motor-metacognitive group was more than that in the motor and motor-cognitive groups ($p < 0.05$).

Conclusion: According to the results obtained, it seems that if motor interventions are combined with cognitive and metacognitive activities, they can have more cognitive and motor benefits for preschool children.

Key Words: Child, Executive function, Metacognition, Motor skills.

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****Corresponding Author:***

Fahimeh Rezaei, Department of Motor Behavior, Faculty of Physical Education and Sport Sciences, Urmia University, Urmia, Iran. Email: f.rezaei.tu@gmail.com

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1- INTRODUCTION

The first years of life are critical in terms of the development of fundamental motor skills (1). Fundamental motor skills are important for participating in physical activity in childhood and later stages of life (2) and have a decisive role in achieving a healthy weight status (3) and the acquisition of sports skills (4). High competence in fundamental motor skills is significantly associated with cognitive and emotional development (5). Furthermore, cognitive skills that are essential for the all-round development of children develop faster during the preschool years, along with the growth of neural networks connected to the prefrontal cortex, and a wide range of them develop in early childhood (6, 7). Cognitive skills in children are recognized as an important aspect of school readiness and predict later academic outcomes and success in school (7). These findings provide a strong rationale for developing cognitive and fundamental motor skills in the first years of life; and their importance has been emphasized by policymakers (6, 8).

There is evidence that motor interventions play an essential role in the development of motor (9-11) and cognitive (11-13) skills in children. Experts suggest that motor programs and interventions should be started during the preschool years (6, 8). It seems that motor interventions can play an important role in the improvement of cognitive and fundamental motor skills (1). However, the main problem, i.e., the lack of sufficient information regarding the effects of different motor programs and suitable interventions to improve these skills in early childhood still exists (12, 14).

Recent efforts to investigate the qualitative aspects of physical activity and the enrichment of motor interventions have evaluated the combination of motor and cognitive activities that are presented sequentially or simultaneously as useful for promoting the motor (15-17) and cognitive (12, 16, 18, 19) skills of children. It is said that such motor activities, which are designed with a focus on creating cognitive engagement during movement, are likely to provide a unique form of stimulation that can have a significant impact on children's cognitive and motor development (13, 20). However, in the study of Egger et al. (21), it was observed that cognitive engagement during physical activity may worsen the cognitive performance of children. These results are discussed in light of theories that predict both the facilitating and detrimental effects of motor-cognitive activities.

The use of metacognitive strategies while performing motor skills is also another form of exercise program, the most important advantage of which is that it enables a person to be aware of his/her learning activity and how his/her work is progressing, and to know his/her strengths and weaknesses (22, 23). Studies have shown that the simultaneous training of metacognitive strategies and motor programs is more effective in improving the working memory (24) and fundamental motor skills (25) of children than when these programs are used separately. MacIntyre et al. (26) also described metacognition as a window for the emergence of skillful performance, which helps to acquire sports skills and raise the level of performance. However, like other field information processings, metacognitive processes do not always lead to better results, and more studies are needed in this field (26).

Finally, considering the importance of the development of cognitive and fundamental motor skills in early childhood, the present study aims to investigate the effects of cognitive and metacognitive factors in motor interventions on the motor and cognitive skills of preschool children. In this study, a motor-cognitive intervention that exposed children to games and activities combined with physical and cognitive demands was designed with the aim of training the participants in cool executive function skills (e.g., rule changes and response to target stimuli and inhibit from non-target stimuli) and increasing their cognitive engagement while playing games and motor activities; and it was compared with a motor intervention with low cognitive engagement, including the same physical demands but without imposing any external or additional cognitive demands. Investigating the effect of combining motor and cognitive activities is not a new topic, but only a few studies have investigated it in preschool children (17, 19). Moreover, most of the previous studies have focused on young children’s cognitive and academic skills (12, 18), and the effect of combined interventions on motor skills has been investigated in only a limited number of studies (17). Furthermore, some studies conducted in this field on children (15, 16) have only utilized one control group that maintained their regular daily activities without including an additional group that solely received motor intervention for comparison with the motor-cognitive intervention group. Thus, there is a need for more studies to investigate the effect of combined interventions on the cognitive and motor performance of children. This will help determine whether motor-cognitive interventions yield more beneficial outcomes than motor interventions in improving both the motor and cognitive skills of children. On the other hand, in the field of games and motor activities, few studies have focused on metacognitive processes as a self-regulated learning strategy to develop fundamental motor skills in preschool children (25). Previous studies have been mainly conducted on adolescents and adults and have investigated the performance and learning of specific motor skills such as volleyball serve (22), forehand topspin in table tennis (27), and soccer dribbling skill (28). In the only study found by the researcher, which used the combination of metacognitive strategies and play at home to develop children's fundamental motor skills, combined intervention led to better results than play at home alone, but this difference was not statistically significant (25); this shows the need for more studies. Also, most of the studies claiming that metacognitive activities lead to the development of cognitive skills in children (29-31) have not used metacognitive strategies while performing motor skills. In the same direction, Hosseini et al. (24) investigated the effect of simultaneous training in aerobics exercise movements and metacognitive strategies on children's verbal working memory. They introduced it as a suitable method compared to using these programs alone; metacognitive strategies were not around the goals of aerobics exercise and were not used to learn the self-regulation of aerobics movements. Therefore, to our knowledge, there is no report on the effect of metacognitive processes while performing motor skills on children's cognitive functions. In this study, considering that both motor interventions and metacognitive interventions are considered useful in improving children's motor (9, 28) and cognitive (12, 29) skills, we hypothesized that a motor-metacognitive intervention provides greater benefits for both cognitive and fundamental motor skills compared to a motor intervention in preschool children. Also, in this study, the differences between the two motor-cognitive and motor-metacognitive interventions, such as awareness of current knowledge, encouragement and emphasis on correct/incorrect answers, and self-evaluation of performance were considered as essential parts of the motor-metacognitive intervention, not present in motor-cognitive intervention. We compared these two approaches to introduce an optimal method to promote cognitive and fundamental motor skills in preschool children.

2- MATERIALS AND METHODS

2-1. Design and Participants

The present study is an applied quasi-experimental research conducted with a pretest-posttest design using a control group. The statistical population consisted of all the children who were enrolled in one of the preschool centers in Tabriz city. The participants in this study were 80 six-year-old male and female (52.5% females) preschool children.

2-2. Inclusion and Exclusion Criteria

Inclusion criteria were: (1) parent satisfaction; (2) absence of the following risk factors or disorders: (a) cardiovascular and respiratory diseases, (b) vision or hearing deficit, and (c) neurodevelopmental disorders such as developmental coordination, autism spectrum, intellectual disability, and attention-deficit hyperactivity. To select the participants based on the inclusion criteria, the schools' management team was asked to introduce the eligible children to participate in the study.

Exclusion criteria included absence from more than two sessions of the intervention and unwillingness of the child or the child's parents to continue cooperation. Children, selected by the convenience sampling method, were randomly assigned into three experimental groups (i.e., motor group, motor-cognitive group, and motor-metacognitive group) and a control group with equal numbers. In the following, 3 participants from the motor group and 4 participants from the motor-cognitive and motor-metacognitive groups were excluded due to the absence from more than two sessions of the intervention, and 3 participants from the control group were excluded due to not attending the post-test. Therefore, the final participants included 66 children (48.5% females). Power analysis using G*Power software showed that 66 participants are sufficient for this study with 95% power (α = 0.05, effect size 0.4).

2-3. Instruments

a) The Bruininks-Oseretsky test of motor proficiency (BOT-2): This test is used to evaluate gross and fine motor skills. In this study, the short form of this test was used. The short form has eight sub-tests and 14 items, which are part of 53 items related to the complete form of the BOT-2. It measures the skills related to agility and strength, body coordination, manual coordination, and fine motion control. In the short form of the BOT-2, one to two items from the complete form have been selected for each sub-test. The validity and reliability of this test have been confirmed (32, 33); and the reliability coefficient has been reported to be above 0.90 (32). In this study, items related to measuring gross motor skills were used.

b) The Head-Toes-Knees-Shoulders task (HTKS): This test directly measures self-regulation by integrating the components of executive functioning into a short game suitable for children aged 4 to 8 years. Construct validity has shown a significant relationship between the HTKS task and cognitive flexibility, inhibitory control, and working memory (34). The HTKS task has three phases with up to four behavioral rules. At first, the examiner gives the child two orders: "Touch your head" and "Touch your toes", and the child naturally responds by touching the head or the toes. The child is then told to do the opposite of what the examiner says. If the child is told to "touch your head", the child must touch his/her toes. If the child answers incorrectly (i.e., touches the head when the examiner tells him/her to touch the head), no score; if the child corrects the movement (i.e., starts to touch the head and then touches the toes), 1 score; and if the child answers correctly (i.e., immediately touches the toes), 2 scores are considered. In the second phase, two new rules "touch your knees" and "touch your shoulders" are added; and as in the previous phase, the child must do the opposite after hearing each order. So, when the child is told to "touch your knees", the child must touch his/her shoulders. This phase includes all of the rules that children have learned so far. In the third phase, the pairs change (i.e., head with knees and toes with shoulders). All three phases presented four experimental trials with feedback and 10 main trials without feedback in a fixed and random manner. Test-retest reliability of this task has been reported to be above 0.90 in various studies (34, 35).

c) The Toulouse-Pieron cancellation test (TP): This test is used to measure selective/sustained attention and processing speed. The test consists of several repetitive squares that have a sequence along one of the corners of each square, with the difference that this sequence is placed in different corners of each square and thus creates various shapes. The instruction of this test is for the child to cancel shapes similar to predefined shapes. For each correct choice, 1 positive score, and for each wrong or forgotten choice, 0.5 negative scores are considered. Sum of the scores is used to obtain the individual score. In this study, the modified form of this test by Rezaiyan et al. (36) was used, in which the squares were bigger and their number was reduced. The internal consistency of the test using the alpha coefficient in the study of Homayoun Firoozjah et al. (37) on six-to-nine-year-old children with mental disorders was 0.84. Its reliability coefficient has also been reported as 0.91 (36).

2-4. Procedure

After the approval of this study by the ethics committee of Urmia University and after obtaining permission from the provincial departments of education, by referring to two preschools and correspondence with the principals and teachers of these schools, the necessary consent was obtained for the participation of children in this study, and the necessary arrangements were made. In addition, all of the children's parents presented their informed consent. The study participants, after recording the pre-test scores, were assigned to one of the following four conditions: (1) experimental condition with a motor intervention; (2) experimental condition with a motor-cognitive intervention; (3) experimental condition with a motor-metacognitive intervention; and (4) control condition under routine care.

The intervention sessions for the experimental groups lasted for six weeks, with three sessions per week and a total of 18 sessions. Each intervention session lasted 50 minutes and was divided into three parts: (a) 5 minutes of warm-up for activities; (b) 40 minutes of activities and games focused on motor skills; and (c) 5 minutes of stretching and cool-down. It should be noted that to increase the efficiency and quality of the interventional sessions, the participants of each experimental group were divided into two classes, and each class received a 50-minute intervention. In this study, two doctoral students of motor behavior who had experienced working in the field of children's games and sports activities led the intervention sessions separately for the experimental groups. After completing the interventional sessions, all three experimental groups along with the control group participated in the post-test to clarify the effectiveness of the interventions.

2-5. Interventions

a) Motor intervention: This intervention included activities and games appropriate to children's age to promote locomotor skills (activities such as moving forward and backward, running, sliding, hopping, and jumping), object control skills (activities such as catching or throwing a ball or sports bean bag, and one/two-handed dribble), stability skills (activities such as heel-to-toe walking on a line, walking with toes on straight and curved lines, spinning on one leg, and angel balance movement), and hand-eye coordination (activities such as hitting a balloon and keeping it in space, chasing a pendulum ball and hitting it with the index finger). The intervention sessions started with the practice of stability skills and were completed with the practice of locomotor and object control skills. At the end of the sessions, hand-eye coordination games were used. The practice program of the interventional sessions was already known, and the planning of games and activities was done from simple to difficult. For example, in the initial sessions, the motor skills of walking and running were included in the games, and then in the later sessions, sliding, hopping, and jumping skills were used. Practicing the manipulative skills, in the initial sessions, larger balls and shorter distances were used. In the next sessions, the size of the balls was smaller, and the distance between throws and catches was increased, and targeting activities with the ball were also added.

b) Motor-cognitive intervention: This intervention was a combination of motor and cognitive activities. The presented motor program was similar to the motor intervention program in terms of games and activities; and the presented cognitive program included training of cool executive function skills. In this combined intervention, games and motor activities were presented in such a way as to create more cognitive engagement and specifically challenge executive functions. To design such activities, as in previous studies (15, 18), a series of verbal commands were used. In this way, in the first level,children performed various skills (such as walking forward, jumping, etc.), but only when the coach gave the relevant verbal command "e.g., naming a specific animal". Then, at a difficult level, they had to perform "contrary to commanded activity" or "predetermined paired activity" (e.g., walking backwards instead of forwards or hopping instead of jumping). Therefore, the children needed to remember and update the new information during the game to execute or inhibit the skills, depending on the verbal command. Another type of verbal command was also given to the children, in that the child was asked to focus on the shapes drawn on the floor, on defined colors or shapes, and to jump or dribble the ball. At a difficult level, the child had to perform jumping or dribbling the ball actions on colors or shapes in the order mentioned. In addition, cognitive-motor dual tasks were used in this intervention (e.g., walking with toes while reciting poetry or doing the angel balance movement while counting numbers).

c) Motor-metacognitive intervention: This intervention was a combination of motor and metacognitive activities. The motor program in this intervention was also similar to the program of the other two groups in terms of games and activities, with the difference that in order to stimulate metacognition, children were given the opportunity to think carefully about how they could perform an activity efficiently. They then were to monitor their own performance in terms of correctness or incorrectness, correct it if necessary, and evaluate the result of their efforts based on the criteria. Finally, they had to think and determine what actions could be taken to achieve their goal next time. For this purpose, a semi-structured interview was used. The interview questions were designed in accordance with the recent literature on increasing metacognitive activity (22, 27). During the practice sessions, children answered four categories of questions related to planning (goal setting, activity analysis, and strategic planning; e.g., based on what you have learned, what do you need to do to throw the ball to the target? or how can you jump higher and farther?); monitoring (self-observation; e.g., do you check your performance after performing the activity? Stop and think about your performance. Was your throw accurate?); evaluation (self-judgment and causal documents; e.g., how accurate was the activity performed by you? Can you explain why your throw was not in the target area?); and reflection (processing experiences; e.g., if you were to do this activity again, how would you do it? or what will you throw the ball into the target area correctly?). In this way, during the sessions, the coach regularly encouraged the children to think about their performance. It should be noted that the necessary explanations for doing the activities were provided by the coach, and all the questions were about the objectives of the game and activities.

2-6. Data Analysis

First, the data were checked for normality and outliers, and the results showed that the data distribution is normal (skewness and kurtosis < 2). Next, a one-way analysis of variance (ANOVA) was used to identify gender differences and group differences in the pre-test stage. The results showed that the gender of the participants did not play a role in the effectiveness of the study interventions. Also, in the examination of group differences in the pre-test stage, no significant difference was observed in variables related to cognition, but there was a significant difference in variables related to movement. Thus, a 2 (time) × 4 (group) repeated measures MANOVA was used to investigate the effects of the study interventions on cognitive skills, and a multivariate analysis of covariance (MANCOVA) was used for motor skills. In this study, data analysis was done using SPSS Statistics 22, with a p-value (< 0.05).

3- RESULTS

The demographic characteristics of the participants are shown in **Table 1**, and the descriptive statistics related to the study variables are shown in **Fig. 1**.

Table-1: The demographic characteristics of the participants

Variables	Motor group (*N* = 17)	Motor-Cognitive group (*N* = 16)	Motor-Metacognitive group (*N* = 16)	Control group (*N* = 17)
Gender (Girl, n (%))	7 (41.2%)	8 (50%)	7 (43.8%)	10 (58.8%)
Weight (Kg, M (SD))	20.53 (1.62)	20.44 (1.50)	20.50 (1.83)	20.18 (1.24)
Height (Cm, M (SD))	114.00 (3.04)	113.88 (1.82)	112.69 (1.49)	114.18 (2.90)
BMI (Kg/m^2, M (SD))	15.77 (0.65)	15.75 (1.19)	15.69 (2.01)	15.58 (0.56)

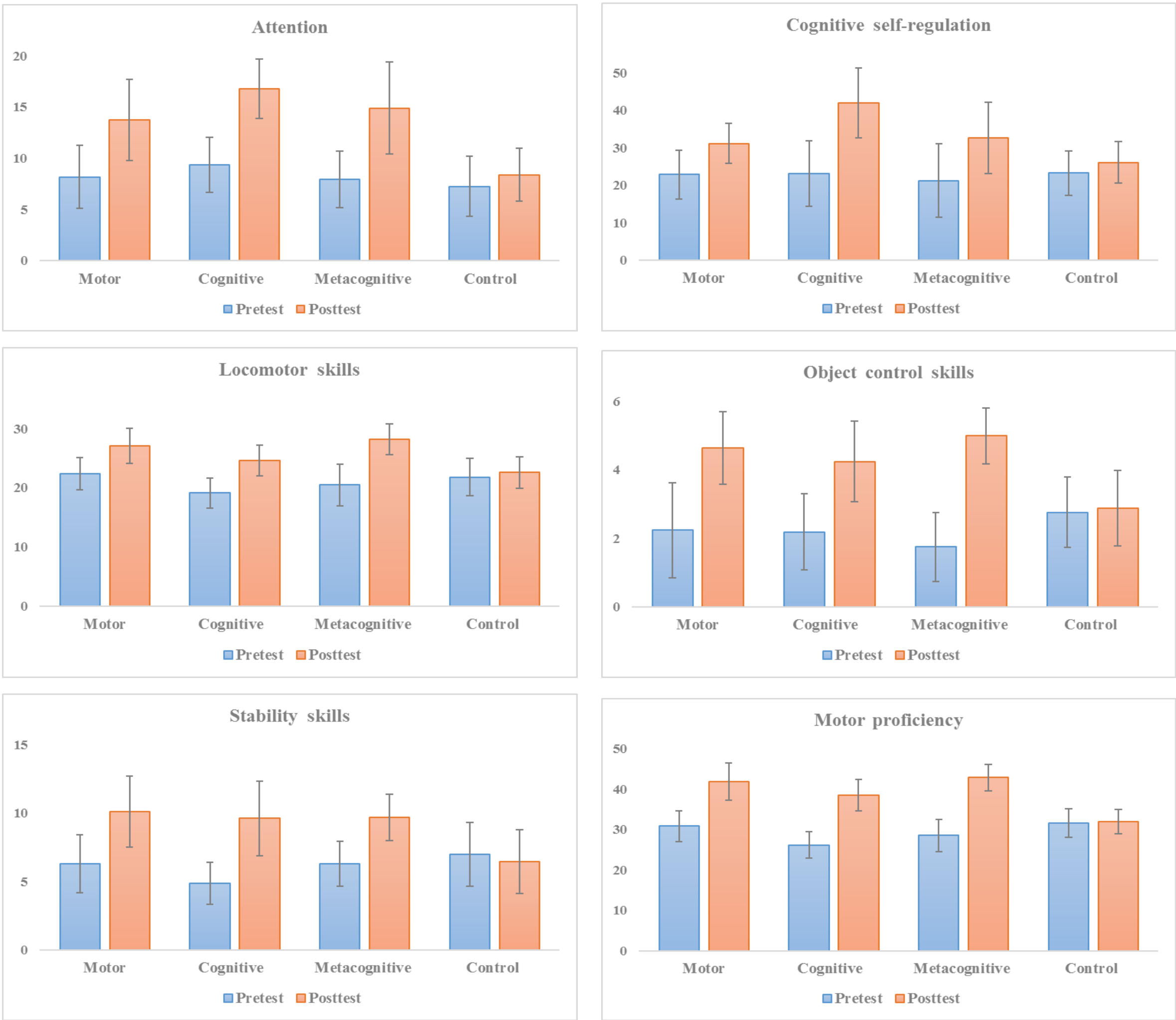

Fig. 1: The error bar graph for motor and cognitive variables

A 2 (time) × 4 (group) repeated measures MANOVA was used to investigate the effects of the study interventions on cognitive skills. The results showed that the main effect for time [Wilk's L=0.09, F(2, 61)=319.35, $p<0.001$, partial $\eta^2=0.91$], the main effect for group [Wilk's L=0.65, F (6, 122)=4.93, $p<0.001$, partial $\eta^2=0.20$], and the main effect for the interaction of time × group [Wilk's L=0.26, F (6, 122)=19.84, $p<0.001$, partial $\eta^2=0.49$] are significant. The follow-up univariate tests for the interaction of time × group showed significant differences in attention [F (3, 62) =34.30, $p<0.001$, partial $\eta^2=0.62$], and cognitive self-regulation [F (3, 62) =17.30, $p<0.001$, partial $\eta^2=0.46$]. The results of pairwise comparisons using the Bonferroni post-hoc test showed that in both cognitive variables, the difference over time (pretest-posttest) in all three motor, motor-cognitive, and motor-metacognitive groups was significant ($p<0.001$).

The follow-up univariate tests for the group also showed significant differences in attention [F (3, 62) =8.53, $p<0.001$, partial $\eta^2=0.29$], and cognitive self-regulation [F (3, 62) =3.69, $p=0.016$, partial $\eta^2=0.15$]. According to the results of pairwise comparisons using the Bonferroni post-hoc test (see **Table 2**), the motor-cognitive group had significant improvements in cognitive variables compared to the control group. The motor and motor-metacognitive groups also showed significant improvements in the attention variable compared to the control group, but this improvement was not significant in the cognitive self-regulation variable. Moreover, no significant difference was observed between the three experimental groups in cognitive variables.

Table-2: The results of the pairwise comparison between the four study groups in cognitive variables

Variables	Group (I)	Group (J)	Mean Difference (I-J)	Std. Error	Sig
Attention	Motor	Cognitive	-2.12	1.07	0.310
	Motor	Metacognitive	-0.44	1.07	1.000
	Cognitive	Metacognitive	1.69	1.09	0.751
	Motor	Control	3.15	1.05	0.024*
	Cognitive	Control	5.27	1.07	0.001**
	Metacognitive	Control	3.58	1.07	0.008**
Cognitive self-regulation	Motor	Cognitive	-5.50	2.45	0.169
	Motor	Metacognitive	0.12	2.45	1.000
	Cognitive	Metacognitive	5.63	2.48	0.162
	Motor	Control	2.35	2.41	1.000
	Cognitive	Control	7.86	2.45	0.013*
	Metacognitive	Control	2.23	2.45	1.000

* p-value (< 0.05) ** p-value (< 0.01)

A multivariate analysis of covariance (MANCOVA) was used to investigate the effects of the study interventions on motor skills. Before performing the main analysis, the assumption of homogeneity of the regression slope was examined, and the results showed that there is no significant interaction between the covariate and the independent variables (P> 0.05). Next, the results of MANCOVA showed that there is a significant statistical difference between the study groups after controlling the pre-test scores [Wilk's L = 0.15, F = 18.19, p < 0.001, partial $\eta^2 = 0.47$]. The follow-up univariate tests showed significant differences in locomotor skills [F (3, 59) = 30.51, p < 0.001, partial $\eta^2 = 0.61$], object control skills [F (3, 59) = 30.06, p < 0.001, partial $\eta^2 = 0.61$], stability skills [F (3, 59) = 21.37, p < 0.001, partial $\eta^2 = 0.52$], and motor proficiency [F (3, 59) = 70.40, p < 0.001, partial $\eta^2 = 0.78$]. According to the results of pairwise comparisons using the Bonferroni post-hoc test (see **Table 3**), all three motor, motor-cognitive, and motor-metacognitive groups had significant improvement in motor variables compared to the control group. The motor-metacognitive group also showed significant improvements in locomotor skills, object control skills, and motor proficiency compared to the motor and motor-cognitive groups. Also, no significant difference was observed between the motor and motor-cognitive groups.

Table-3: The results of the pairwise comparison between the four study groups in motor variables

Variables	Group (I)	Group (J)	Mean Difference (I-J)	Std. Error	Sig
Locomotor skills	Motor	Cognitive	0.27	0.73	1.000
	Motor	Metacognitive	-2.31	0.68	0.007**
	Cognitive	Metacognitive	-2.58	0.70	0.003**
	Motor	Control	4.19	0.66	0.001**
	Cognitive	Control	3.92	0.75	0.001**
	Metacognitive	Control	6.50	0.70	0.001**
Object control skills	Motor	Cognitive	0.28	0.32	1.000
	Motor	Metacognitive	-0.71	0.30	0.120
	Cognitive	Metacognitive	-0.99	0.31	0.012*
	Motor	Control	2.05	0.29	0.001**
	Cognitive	Control	1.76	0.33	0.001**
	Metacognitive	Control	2.75	0.31	0.001**
Stability skills	Motor	Cognitive	-0.66	0.71	1.000
	Motor	Metacognitive	0.36	0.66	1.000
	Cognitive	Metacognitive	1.02	0.68	0.850
	Motor	Control	4.31	0.64	0.001**
	Cognitive	Control	4.97	0.73	0.001**
	Metacognitive	Control	3.95	0.68	0.001**
Motor proficiency	Motor	Cognitive	-0.11	1.03	1.000
	Motor	Metacognitive	-2.66	0.96	0.043*
	Cognitive	Metacognitive	-2.55	0.99	0.075
	Motor	Control	10.54	0.93	0.001**
	Cognitive	Control	10.65	1.06	0.001**
	Metacognitive	Control	13.20	0.99	0.001**

* p-value (< 0.05) ** p-value (< 0.01)

4- DISCUSSION

The present study was conducted to investigate and compare the effects of cognitive and metacognitive factors in motor interventions on the motor and cognitive skills of preschool children. The findings showed that in cognitive skills (attention and cognitive self-regulation), the difference over time (pretest-posttest) is significant in all three motor, motor-cognitive, and motor-metacognitive groups. Also, all three interventional groups had significant improvements in attention scores compared to the control group. However, in cognitive self-regulation, only the motor-cognitive group showed a significant improvement compared to the control group. Therefore, the results of this study show the superiority of motor-cognitive intervention in improving cognitive skills of preschool children. Also, the findings of this study indicate that all three types of motor, motor-cognitive, and motor-metacognitive interventions lead to the improvement of fundamental motor skills in preschool children. However, motor-metacognitive intervention is more effective in improving fundamental motor skills compared to both motor and motor-cognitive interventions.

The findings of this study are in accordance with the results of previous studies regarding the significant increase of cognitive skills in children through motor (11-13), motor-cognitive (12, 16, 18), and motor-metacognitive (24) interventions. However, in a study by Lee et al. (38), a program based on fundamental motor skills had no effect on the cognitive performance of elementary children, which is inconsistent with the findings of the present study. These conflicting results in the research literature may be due to differences in the cognitive skills measured and the use of different tools to assess cognitive performance. In this regard, it has been observed that the effect of motor activity on cognition is selective and depends on the nature of targeted cognitive functions as well as their brain substrates (39). Also, in the study of Wen et al. (40), mini-trampoline physical activity did not affect the development of preschool children's executive functions, which is one of the other studies inconsistent with the present study. The reason for this disparity can be considered to be the difference in the type of intervention used in the two studies. In the study of Wen et al. (40), physical activity intervention was used, and in the present study, motor skill intervention was used to improve the cognitive skills of children. In this regard, in a systematic review, it was observed that motor skill interventions have a greater effect on the cognitive skills of preschool children compared to physical activity interventions (12).

In explaining the results obtained from the present study regarding the effectiveness of motor intervention on cognitive skills, evidence from neuropsychological data and neuroimaging shows that motor and cognitive behaviors considerably share neural substrates. The dorsolateral prefrontal cortex, the cerebellum, and connecting structures, including the basal ganglia, are involved in this neural circuit. This circuit is activated during motor and cognitive tasks, and the output of this neural network affects the control of both (41, 42). In other words, during motor experience, the activities in the brain areas related to cognition increases, and thus cognitive skills improve. Also, motor skill learning can lead to changes in brain plasticity, increase brain angiogenesis and synaptogenesis, and improve the structure and function of the brain (13).

In relation to the effect of combining motor interventions with metacognitive strategies, studies have shown that metacognitive activities lead to the development of cognitive skills in children (29-31). Therefore, it was expected in this study that motor-metacognitive intervention would bring more cognitive benefits compared to motor intervention. However, like the motor group, the motor-metacognitive group only showed a significant improvement in attention scores compared to the control group, although with a higher significance level. Since, to our knowledge, there is no report on the effect of metacognitive processes while performing motor skills on preschool children's cognitive functions, we could not make a comparison with the results of previous studies. However, in a study by Hosseini et al. (24), it was observed that the effect of simultaneous training of aerobics exercise movements and metacognitive strategies on the verbal working memory of second and third grade students with learning disabilities is statistically greater than that when these programs are used alone, which is not consistent with the results of the present study. This contradiction in the results can be attributed to the difference in the type of cognitive skill measured and the difference in the conditions and age of the participants in the two studies. Moreover, in the present study, the intervention duration was six weeks. It is possible that more time is needed to reveal differences between motor and motor-metacognitive interventions in effectiveness on children's cognitive skills. Therefore, the need for more studies in this field is felt.

In relation to the effect of combining motor interventions with cognitive activities, in the present study, although no statistically significant difference was observed between the motor-cognitive group and the motor and motor-metacognitive groups, in cognitive self-regulation, only the motor-cognitive group showed statistically better performance compared to the control group. Therefore, in this study, motor-cognitive intervention was more effective in improving cognitive skills. This finding is consistent with the results of previous studies reporting that interventions integrating cognitive and motor components were more effective in producing cognitive and neurological benefits for children (12, 17, 43). However, in the study of Eger et al. (21), cognitively engaging physical activity worsened the cognitive performance of children, which is inconsistent with the results of the present study. Also, in the study of Bulten et al. (44), inconsistent with our findings, it was found that cognitively engaging physical activity was not superior to physical activity alone in influencing children's executive functions. This conflict in the results can be attributed to factors such as significant variability in cognitive tasks used, intervention demands, duration and type, and participant demographics. For example, acute interventions were used in the aforementioned studies, but six-week interventions were used in the present study. In this regard, it has been reported that the majority of effective motor-cognitive programs in different studies have been run for six weeks to six months (18).

In explaining the results obtained from this study regarding the increasing effect of combining motor interventions with cognitive activities, physiological and neurological processes and mechanisms can be mentioned. In this context, it has been stated that physical activity may improve the brain metabolism and its flexibility, and the accompanying cognitive engagement by increasing the brain metabolism and guiding the flexibility process leads to the improvement of the efficiency of the nervous system as much as possible (20). It has also been observed that motor-cognitive activities rely on a process called neural plasticity, which can create new neuronal connections and increase synapses in different areas of the brain. Therefore, the brain can modify its activity in response to specific simulations (45, 46).

Another finding of the present study was that all three types of motor, motor-cognitive, and motor-metacognitive interventions are effective in improving the fundamental motor skills of preschool children. This finding is consistent with the results of previous studies regarding the significant increase of motor skills in children through motor (9-11), motor-cognitive (15-17), and motor-metacognitive (25) interventions. However, a study conducted by Foulkes et al. (47) did not show significant improvement in fundamental motor skills after a six-week active play intervention, which is inconsistent with the results of the present study. It should be noted that the intervention employed in that study was not specifically designed to target fundamental motor skills and had differences in terms of frequency and volume of training compared to the intervention used in our study. These differences in the training program might have probably led to the contradictory findings between the two studies. Also, in the study of Duncan et al. (17), it was found that the combination of movement and story-telling is more effective in improving motor competence compared to movement alone. This finding is not consistent with the results of our study, which found no statistically significant difference between motor and motor-cognitive interventions in improving motor skills. In the present study, we used a motor-cognitive intervention that specifically targeted and challenged executive functions while playing games and motor activities. This training program is different from the program used in Duncan et al.'s study. Hence, it is not possible to make a complete comparison between the results of these two studies. Overall, further studies are needed to determine whether motor-cognitive interventions yield more beneficial outcomes in improving preschool children's fundamental motor skills compared to motor interventions alone or not.

Another finding of the present study was that motor-metacognitive intervention is more effective in improving fundamental motor skills compared to motor and motor-cognitive interventions. In this regard, previous studies investigating the effect of using metacognitive strategies during training motor skills on the performance and learning of volleyball serve (22), forehand topspin in table tennis (27), and soccer dribbling skill (28) have found it effective. Similarly, MacIntyre et al. (26), in line with our study, found metacognitive processes useful for acquiring skills and raising performance levels. Also, in a study by Alimardani et al. (25), it was observed that metacognitive strategies and play at home led to better results than play at home alone, but this difference was not statistically significant. However, in the present study, a statistically significant difference was observed in locomotor skills, object control skills, and motor proficiency between the intervention groups, and the combination of motor intervention with metacognitive strategies led to greater motor improvement in children. In explaining the results obtained from the present study, brain imaging studies show the circuit of attention networks involved in the process of metacognitive control, whose source is located in the middle frontal areas. These areas are active during conflict resolution, error correction, and emotional regulation. Thus, it can influence athletic and motor performance (48). Indeed, metacognitive strategies help children learn concepts and strategies, figure out how to do a skill or game more enjoyably, and focus their attention on how to complete tasks. Children also need to assess their performance and increase their motor awareness so that they can effectively improve and learn their motor skills by being more aware and thinking about the specific mistakes they have made. These processes help the child become more cognitively engaged in the task because she/he is not just practicing a motor skill but rather understands better what is correct or incorrect (23).

4-1. Limitations of the study

The present study had some limitations. The sample size was relatively small, and it is necessary to repeat this study with a larger sample so that the results obtained are more reliable. In this study, although two trained coaches who had academic and practical experience in the field of children's sports and games were used to increase the percentage of confidence in creating and controlling training conditions in different groups, the standard tool that evaluates the amount of cognitive and metacognitive engagement created for the participants of all three experimental groups during the intervention sessions was not used. The reason for that was the time limits in the intervention sessions and the lack of skilled assistants. It is suggested to carry out similar studies considering this limitation in future studies. Moreover, in this study, especially in cognitive variables such as attention, no significant difference was observed between the experimental groups, which could be due to the short duration of the intervention. It is possible that in a longer intervention, the differences between the effectiveness of the three interventions would become more apparent. Therefore, the use of a longer intervention is suggested in future studies.

5- CONCLUSION

Overall, the results of the present study show that motor programs can serve as the basis of a holistic approach to child development and support not only physical health but also the cognitive and motor development of children. However, it seems that cognitively engaging motor interventions that combine motor and cognitive tasks may act as brain stimulators and provide additional cognitive benefits for preschool children. Hence, when the aim is to improve cognitive performance through motor interventions, games and activities that expose children to a combination of cognitive and motor demands are a better option. Also, it seems that motor interventions along with metacognitive strategies can be effective in the development of preschool children's motor skills and achieve better results than motor and motor-cognitive interventions. Hence, it is recommended for children's sports and game coaches to use metacognitive learning strategies to improve and develop motor skills in children. In general, the findings of this study provide useful information to coaches, therapists, and motor behavior specialists on how to design motor programs to increase motor competence and cognitive ability in early childhood. However, since it is the first time to compare the effects of all three types of motor, motor-cognitive, and motor-metacognitive interventions in one study, this study calls for more research in this field.

6- ETHICAL CONSIDERATIONS

All ethical principles were considered in this study. Children and their parents were informed of the purpose of the research and its implementation stages. They were also assured about the confidentiality of their information and were free to leave the study whenever they wished; and if desired, the research results would be available to them. Written consent forms were also obtained from children's parents. This study was approved by the Ethics Committee of Urmia University.

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8- CONFLICT OF INTEREST

None.

9- REFERENCES

1. Payne VG, Isaacs LD. Human motor development: A lifespan approach. 9th ed: New York: Routledge; 2017.

2. Loprinzi PD, Davis RE, Fu Y-C. Early motor skill competence as a mediator of child and adult physical activity. Preventive medicine reports. 2015; 2:833-8.

3. Barnett LM, Webster EK, Hulteen RM, De Meester A, Valentini NC, Lenoir M, Pesce C, Getchell N, Lopes VP, Robinson LE, Brian A, Rodrigues LP. Through the looking glass: A systematic review of longitudinal evidence, providing new insight for motor competence and health. Sports Medicine. 2022; 52(4):875-920.

4. Schembri R, Quinto A, Aiello F, Pignato S, Sgrò F. The relationship between the practice of physical activity and sport and the level of motor

competence in primary school children. Journal of Physical Education and Sport. 2019; 19:1994-8.

5. Li Q, Wang Q, Xin Z, Gu H. The Impact of Gross Motor Skills on the Development of Emotion Understanding in Children Aged 3–6 Years: The Mediation Role of Executive Functions. International Journal of Environmental Research and Public Health. 2022; 19(22):14807.

6. Gizzonio V, Bazzini MC, Marsella C, Papangelo P, Rizzolatti G, Fabbri-Destro M. Supporting preschoolers' cognitive development: Short-and mid-term effects of fluid reasoning, visuospatial, and motor training. Child Development. 2022; 93(1):134-49.

7. Zelazo PD, Carlson SM. The neurodevelopment of executive function skills: Implications for academic achievement gaps. Psychology & Neuroscience. 2020; 13(3):273-98.

8. Singh R, Pattisapu A, Emery MS. US Physical Activity Guidelines: Current state, impact and future directions. Trends in cardiovascular medicine. 2020; 30(7):407-12.

9. Koolwijk P, Hoeboer J, Mombarg R, Savelsbergh G, de Vries S. Fundamental movement skill interventions in young children: a systematic review. International Journal of Sport and Exercise Psychology. 2023:1-23.

10. Engel A, Broderick C, van Doorn N, Hardy L, Ward R, Kwai N, Parmenter B. Effect of a fundamental motor skills intervention on fundamental motor skill and physical activity in a preschool setting: a cluster randomized controlled trial. Pediatric Exercise Science. 2021; 34(2):57-66.

11. Jane JY, Burnett AF, Sit CH. Motor skill interventions in children with developmental coordination disorder: a systematic review and meta-analysis. Archives of physical medicine and rehabilitation. 2018; 99(10):2076-99.

12. Jylänki P, Mbay T, Hakkarainen A, Sääkslahti A, Aunio P. The effects of motor skill and physical activity interventions on preschoolers' cognitive and academic skills: A systematic review. Preventive Medicine. 2022; 155:106948.

13. Shi P, Feng X. Motor skills and cognitive benefits in children and adolescents: Relationship, mechanism and perspectives. Frontiers in Psychology. 2022; 13:1017825.

14. Dapp LC, Gashaj V, Roebers CM. Physical activity and motor skills in children: A differentiated approach. Psychology of Sport and Exercise. 2021; 54:101916.

15. Zamani Sani H, Hasanpour V, Fathi Rezaei Z, A G. The effectiveness of cognitive-motor exercises on the motor development of children with autism based on Gentile's two-stage model. Research in Sport Management and Motor Behavior. 2021; 11(21):109-23.

16. Korkusuz S, Top E. Does the combination of physical activity and attention training affect the motor skills and cognitive activities of individuals with mild intellectual disability? International Journal of Developmental Disabilities. 2023; 69(5):654-62.

17. Duncan M, Cunningham A, Eyre E. A combined movement and story-telling intervention enhances motor competence and language ability in preschoolers to a greater extent than movement or story-telling alone. European Physical Education Review. 2019; 25(1):221-35.

18. Schmidt M, Mavilidi MF, Singh A, Englert C. Combining physical and cognitive training to improve kindergarten children's executive functions: A cluster randomized controlled trial. Contemporary Educational Psychology. 2020; 63:101908.

19. Vazou S, Mavilidi MF. Cognitively Engaging Physical Activity for Targeting Motor, Cognitive, Social, and Emotional Skills in the Preschool Classroom: The Move for Thought preK-K Program. Frontiers in Psychology. 2021; 12:729272.

20. Rahe J, Becker J, Fink GR, Kessler J, Kukolja J, Rahn A, Rosen JB, Szabados F, Wirth B, Kalbe E. Cognitive training with and without additional physical activity in healthy older adults: cognitive effects, neurobiological mechanisms, and prediction of training success. Frontiers in aging neuroscience. 2015; 7:187.

21. Egger F, Conzelmann A, Schmidt M. The effect of acute cognitively engaging physical activity breaks on children's executive functions: Too much of a good thing? Psychology of sport and exercise. 2018; 36:178-86.

22. Chatzipanteli A, Digelidis N. The influence of metacognitive prompting on students' performance in a motor skills test in physical education. International Journal of Sports Science and Engineering. 2011; 5(2):93-8.

23. Chatzipanteli A, Grammatikopoulos V, Gregoriadis A. Development and evaluation of metacognition in early childhood education. Early child development and care. 2014; 184(8):1223-32.

24. Hosseini M, Mahdian H, Hamidi F. Effectiveness of aerobic, cognitive and metacognitive strategies and simultaneous training on verbal working memory of students with specific learning disability in writing Journal of Analytical-Cognitive Psychology. 2021; 12(45):53-66.

25. Alimardani A, Shahbazi M, Tahmasebi Boroujeni S, Arab Ameri E. The effect of metacognitive strategies and play at home (UNICEF Proposed Package) on learning fundamental motor skills in children aged 5 to 8 years in the pandemic of Corona disease. Motor Behavior. 2022.

26. MacIntyre TE, Igou ER, Campbell MJ, Moran AP, Matthews J. Metacognition and action: a new pathway to understanding social and cognitive aspects of expertise in sport. Frontiers in psychology. 2014; 5:1155.

27. Rahavi Ezabadi R, Sadeghian Shahi MR, Rezaei E. The Effects of Instruction of Learning Strategies and Difficulty of Decision Making on the Accuracy of Forehand TopSpin in Table Tennis. Sport Psychology Studies (ie, motaleat ravanshenasi varzeshi). 2019; 7(26):77-90.

28. Susaki Y. Self-regulated learning and motor skills: effects of a physical education intervention program on Japanese college students. Journal of Physical Education and Sport. 2021; 21(6):3593-8.

29. Altan RY, Temel ZF. The Effect of Metacognitive Strategy-Based Geometry Education on Young Childrens' Metacognitive and Executive Functions Skills. Pegem Journal of Education and Instruction. 2023; 13(2):297-313.

30. Jones JS, Milton F, Mostazir M, Adlam AR. The academic outcomes of working memory and metacognitive strategy training in children: A double-blind randomized controlled trial. Developmental science. 2020; 23(4):e12870.

31. Bayrami M. The effectiveness of self-regulation training on executive functions and reading performance of dyslexic students. Journal of Modern Psychological Researches. 2013; 8(29):43-66.

32. Bruininks RH, Bruininks BD. Bruininks-Oseretsky Test of Motor Proficiency: Manual. Pearson Assessments: Circle Pines, MN: AGS Publishing; 2005.

33. Fathirezaie Z, Abbaspour K, Badicu G, Zamani Sani SH, Nobari H. The effect of environmental contexts on motor proficiency and social maturity of

children: An ecological perspective. Children. 2021; 8(2):157.

34. McClelland MM, Cameron CE, Duncan R, Bowles RP, Acock AC, Miao A, Pratt ME. Predictors of early growth in academic achievement: The head-toes-knees-shoulders task. Frontiers in psychology. 2014; 5:599.

35. McClelland MM, Cameron CE. Self-regulation in early childhood: Improving conceptual clarity and developing ecologically valid measures. Child development perspectives. 2012; 6(2):136-42.

36. Rezaiyan A, Mohammadi E, Fallah PA. Effect of computer game intervention on the attention capacity of mentally retarded children. International journal of nursing practice. 2007; 13(5):284-8.

37. Homayounnia Firoozjah M, Sheikh M, Hemayattalab R, Shahrbanian S. The environmental approach (affordances) approach to the attention and memory of children with mental disorders. Shenakht Journal of Psychology and Psychiatry. 2019; 6(1):35-48.

38. Lee J, Zhang T, Chu TL, Gu X, Zhu P. Effects of a fundamental motor skill-based afterschool program on children’s physical and cognitive health outcomes. International journal of environmental research and public health. 2020; 17(3):733.

39. Eskandarnejad M, Rezaei F. The effect of aerobic exercise on neural networks of attention and working memory. The Neuroscience Journal of Shefaye Khatam. 2018; 6(2):31-40.

40. Wen X, Zhang Y, Gao Z, Zhao W, Jie J, Bao L. Effect of mini-trampoline physical activity on executive functions in preschool children. BioMed research international. 2018; 2018:2712803.

41. Diamond A. Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. Child development. 2000; 71(1):44-56.

42. Hanakawa T. Rostral premotor cortex as a gateway between motor and cognitive networks. Neuroscience research. 2011; 70(2):144-54.

43. 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):575-91.

44. 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.

45. Black JE, Isaacs KR, Anderson BJ, Alcantara AA, Greenough WT. Learning causes synaptogenesis, whereas motor activity causes angiogenesis, in the cerebellar cortex of adult rats. Proceedings of the National Academy of Sciences. 1990; 87(14):5568-72.

46. Eskandarnejad M, Rezaei F. The Effect of Physical Activity with Different Levels of Cognitive Load on the Cingulate Cortex's Brain Waves. Motor Behavior. 2020; 12(40):17-36.

47. Foulkes J, Knowles Z, Fairclough S, Stratton G, O’dwyer M, Ridgers N, Foweather L. Effect of a 6-week active play intervention on fundamental movement skill competence of preschool children: a cluster randomized controlled trial. Perceptual and motor skills. 2017; 124(2):393-412.

48. Fernandez-Duque D, Baird JA, Posner MI. Executive attention and metacognitive regulation. Consciousness and cognition. 2000; 9(2):288-307.