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Article

Effects of exercise on motor and cognitive development in preschoolers

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Abstract: The educational-instructional process, specific to the preschool age of 4–5 years, is oriented towards the formation of children's motor and cognitive skills. As part of physical activities in preschool education, various exercises are performed to strengthen motor and verbal responses. Light physical exercises and movement games are used to improve motor skills and verbal ability. The present research was carried out on a group of 20 preschoolers, using an experimental methodology, with the help of One-Group Pre-test and Post Test Design. Based on the statistical analysis of the data obtained from the motor skills evaluation tests and the cognitive skills evaluation tests, the value $p < 0.001$ indicates a positive statistical significance between the pre-test and the post-test. The values of Cohen's *D* coefficient by which the effect size was evaluated indicate its great influence ($D = 0.893$). In conclusion, the differences between the pre-test and post-test values show significant progress, which underlines the effectiveness of the intervention aimed at improving motor and cognitive skills in preschoolers.

Keywords: cognitive development; concordance; exercise; motor development; preschoolers

1. Introduction

Motor and cognitive development constitute two of the five interrelated domains of school readiness skill development: physical health and motor development, general knowledge, approaches to learning, language development, and socioemotional development (Duncan et al., 2017). Cognitive development does not occur in isolation, but is linked to the stimulation of motor skills (Cheung et al., 2019). Motor development and cognitive development are aimed to be performed simultaneously in pre-school children in order to build their practical ability to use information. Stimulating and varied motor activities have a significant impact on children's intellectual development (Čoh, 2020). According to Gizzonio et al. (2022), effective interventions in early education in terms of cognitive and motor development represent a major challenge for psychologists and preschool teachers.

In the educational-instructional process, designed for 4–5-year-old children, the primary objective is to help them develop according to their individual peculiarities. In the framework of the lessons of practical movement activities, by conducting and organising exercises, simple games, application paths, which ensure the learning of basic motor skills (walking, running, jumping, catching and throwing) and the integration of children in group activities, the aim is to develop motor and cognitive skills. Practical physical activities, carried out repeatedly, contribute to the development of cognitive skills and of human behaviour. The effects of physical activity on motor skills and cognitive development in preschool children have major implications on their physical and mental health (Zeng et al., 2017). The variety of exercises performed with multiple repetitions allow children to retain information and improve their motor ability and their well-being. Children do the exercises until they learn them, constantly becoming skilled at facing different challenges or situations. The motor and cognitive development of pre-school children is influenced by the use of methods, means and forms of organising activities and actions in lessons. Messerli-Bürgy et al. (2021) point out that the late onset of walking was related to weaker motor skills (fine motor skills, static and dynamic balance (all $p < 0.003$)) and weaker cognitive skills (selective attention and visual perception (all $p = 0.001$)) in late preschool age, or delayed inclusion in motor activities has negative effects on motor and cognitive development. At the preschool level, practical physical activities, together with the other activities set out in the curriculum, make a considerable contribution to the child's all-round education, with beneficial effects on motor, biological, social and psychological development. The introduction of breaks in the form of movement into the school curriculum, above a minimum threshold, stimulates cognitively and brings benefits in children's behaviour (Ureña et al., 2020). This research is important and is justified by the special attention to be paid to education and training at this age, and emphasises the relationship between the mind and the body (Albu et al., 2006). Since children's somatic development and improvement of expression of their motor and cognitive skills play a determining role in the evolution of human behaviour, we consider that the topic addressed is relevant for early education. The aim of this study is to highlight the relation between motor and cognitive development in preschoolers through physical exercises.

In physical activities, from the simplest to the most complex, there is a close connection between the motor ability to perform and the cognitive ability represented by the verbal responses of children which represent the information understood, retained and with which the child operates. Motor development is defined as a process of continuous change in motor behavior throughout life, determined by the interaction between the biological structure of the individual, the demands of the motor task and environmental conditions (Gallahue and Ozman, 2022). Cognitive development is "a psycho-socio-biological process of human mental growth and development" (Jena and Paul, 2016). Within the physical activities from the simplest to the most complex, an indestructible connection is made between the motor capacity of execution and the cognitive capacity represented by the children's verbal responses, responses that represent information understood, retained and with which the child operates. At the level of preschool education, practical physical activities, together with the other activities provided for in the current education plan, have a considerable contribution to the integral education of the child, producing beneficial effects on motor, biological, social, psychological development, etc.

Researchers have observed that preschoolers who have the fundamental motor skills needed to participate in play and motor activities also have increased opportunities to develop cognitive skills (Iverson, 2010). Studies in the field highlight bidirectional and reciprocal associations between motor and cognitive development for preschool children (Cameron et al., 2016; van der Fels et al., 2015; Westendorp et al., 2011). There are studies focused on examining the relationship between motor skills and cognitive development in preschoolers (Cheung et al., 2019; Djordjic et al., 2016; Geng et al., 2015; Houwen et al., 2016; Invernizzi et al., 2018; Magallón et al., 2016; Martzog et al., 2019; Messerli-Bürgy et al., 2021; Nugroho et al., 2021; Tortella et al., 2020; Veldman et al., 2019). A recent study (Ansuya et al., 2023) examined the effect of a nutrition-focused intervention on cognitive development among malnourished preschool children aged between 3 and 5 years. Tramontano et al. (2024) compared the impact of dynamic motor cognitive training versus computer-based cognitive training on general cognitive efficiency.

The element of novelty that the current study brings is the creative integration of the exercise for the motor and cognitive development of preschoolers. It was found that individuals with better cognitive development in early childhood appeared to be better prepared for learning and had stronger academic skills throughout the educational process (Bryant et al., 2020), and children with cognitive abilities older ones showed a stronger physical form (Latorre Román et al., 2015; Martel et al., 2021) emphasize the need for a thorough investigation of body representations in order to plan and implement subsequent strategies for the development and remediation of children's activities. Riso et al. (2019) state that verbal conceptual skills are better in children from families with higher education and who participated in activities in sports clubs. According to Pesce et al. (2021), the thorough investigation of bodily representations is important for establishing action strategies and conducting research oriented in three directions: tracking the acquisition of motor skills, improving cognition, the role of physical education in cognitive development, especially executive function and highlighting the role of motor skills in physical, mental and socio-emotional health.

The benefits of exercise are easily perceived in strengthening muscles and joints, educating attention, health, communication and socialization. A number of authors emphasize the positive influence of physical exercise on physical development and academic performance. Tomporowski et al. (2015) believe that exercise and physical training alter children's cognition. Alesi et al. (2016) argue that planning structured sports activity is a natural and enjoyable way to improve cognitive skills. Bryant et al. (2020) associate overall sports participation with cognitive flexibility. Williams et al. (2020) highlight that high levels of fitness are beneficial for cognitive function. According to Jia et al. (2021), the diverse exercise performed has a beneficial role in the cognitive development of the 5–6 year old child. The findings of specialists who have undertaken research in this direction show that a low-dose activity program is an effective means of promoting cognitive efficiency in overweight children (Crova et al., 2014). Increased participation in physical activity influences cognitive functions in children, namely working memory, cognitive flexibility and brain health (Fisher et al., 2011; Howie and Pate, 2012; Kamijo et al., 2011; Kwak et al., 2009). Relationships between objectively and subjectively measured physical activity increase indicators of health status in the first years of life (Carson et al., 2017). Therefore, physical activity and traditional sports should not be replaced by interactive video games, which specialists can use to promote physical activity (Gao et al., 2013). A positive correlation between exercise and academic performance has also been observed among children, likely due to cognitive changes including executive function, memory, and fluid intelligence (Tomporowski et al., 2015). Physical exercises have an immediate cognitive effect, and a single intervention based on the use of exercise can generate benefits in terms of cognitive development (Tomporowski, 2003). Also, some studies (Sánchez-López et al., 2019; Sember et al., 2020) focused on the positive effects of physical exercise on the prefrontal cortex and the hippocampus, emphasizing an increased activation in the prefrontal cortex, involved in cognitive control after exercise interventions.

Teachers can improve the results of preschool children if they design teaching activities that simultaneously contribute to the formation of motor and cognitive skills in the preschool curriculum. In the curriculum for early education, more and more emphasis are placed on the involvement of preschoolers in nature activities through practical interaction with the materials (Yiğit-Gençten and Aydemir, 2023; Yiğit-Gençten et al., 2024). Insufficient preparation in terms of early motor development, limited time has led pre-school teachers to search for ideas on the simultaneous teaching of motor and cognitive skills (Cheung et al., 2019). Øksendal et al. (2021) draw the attention of parents and teachers to the fact that they should be aware that children who struggle with their age-appropriate motor achievements may also be at risk of experiencing peer victimisation, socialising and automatically facing their own shortcomings. It is important to create an engaging environment to provide children with meaningful opportunities to deepen their understanding of basic relational concepts while simultaneously developing basic motor skills.

In carrying out this research, we started from the premise that exercise at the age of 4–5 years contributes to the improvement of motor ability, which is an objective that influences the process of training and formation of human behaviour, which is particularly important for each child.

The main objective of our study consists in the improvement of motor and cognitive skills in physical activity lessons with physical exercises. In order to demonstrate improved motor and cognitive skills, we have established two hypotheses:

- The first hypothesis assumes that performing a set of exercises and games during 24 lessons of physical activity aiming at learning movement actions leads to an improvement of children’s motor skills.
- The second hypothesis that performing a set of exercises and games during 24 lessons of physical activity aiming at learning movement actions in parallel with learning specific information leads to an improvement of children’s cognitive skills.

2. Materials and methods

2.1. Participants

20 children, aged 4–5 years, in Bacău County, from Romania, were involved in this study. The criteria for including the children in the research were the parents’ consent and child’s medical condition. The group of 20 preschoolers was selected mainly according to the criterion of health status. All children presented a level of psychomotor development within the parameters specific to preschool age.

2.2. Methods and instruments

The research methodology is based on a quasi-experiment, which controls the additional variable less strictly and which makes it possible to obtain non-randomized samples (Masuda et al., 2021). The experimental design uses One-Group Pre-test—Post Test Design (Tarnoto et al., 2019; Vicol et al., 2024). The pre-test was given before training and the post-test was conducted after the last training session. In the pre-test and post-test stage, different research instruments were administered to measure the physical, motor and cognitive development of pre-schoolers.

Regarding the assessment of motor development, there were used two measurements for physical development (height with a stadiometer and weight with an electronic scale. For the assessment of motor skills, there were chosen 4 physical events: 5m running starting from a line, throwing a 0.50 kg medicine ball at a distance with 2 hands from the ground, walking on a 5 m line placing foot soles on the line, labyrinth test, in which we used the tape measure and the stopwatch.

Referring to the evaluation of the verbal component of cognitive ability, there were applied two tests (**Table 1**). The first test "Say the opposite word" involves assessing each child separately. The child is asked to give an answer within 15 seconds. For each word, 1 point is scored for an answer requiring teacher's help for up to 4 words, 2 points for an answer requiring teacher's help for up to 2 words and 3 points for an answer not requiring teacher's help. In the second test "Finish the sentence starting from the given word" the child is asked to give an answer and scored 1 point for an answer requiring teacher's help for up to 4 sentences, 2 points for an answer requiring teacher's help for up to 2 sentences and 3 points for an answer not requiring teacher's help.

Table 1. Cognitive ability tests.

Test 1 "Say the opposite word"		**Test 2 "Finish the sentence starting from the given word"**	
I say	You say	I say	You say.
Up	Down	Walk	And swing your arms back and forth.
To the right	To the left	Run	And lift our feet off the ground.
In front	Behind	Roll	Your arms in circles next to your ears.
Ahead	Backwards	Jump	Like a rabbit.
Stretch	Bend	Throw	As far as possible.

Motor ability is assessed both by the level of mastery of motor skills and by the level of development of psychomotor skills or motor qualities. Its progress is determined by individual predispositions, by the amount of movement, by the motivation and interest of each individual in carrying out practical activities, by the emotional and social states which are felt and manifested. Cognitive skills are determined by the ability to understand the meanings of words and their logical combinations. In the psychomotor education lessons, specific to pre-school education, the achievement of cognitive and motor operational objectives, which lead to the development of cognitive and motor skills, is a priority. In the present research, the development of children's cognitive ability was assessed through their verbal responses and the development of motor ability through their motor performance following the execution of practical tests.

2.3. Research procedure

It was established a programme through which physical exercises were conducted in the period September 2021–January 2022. In order to achieve the objectives of the 4-month research, each week there were 2 lessons of practical activity, lasting for 30 minutes, in which the children learned the general basics of movement. At the end of each lesson the children had to repeat some of the information used during the lessons all at once after the teacher. During the activities, walking and running exercises were performed, with various movements or games that contained dynamic and static movements. The teaching approach of physical education to preschoolers followed the national curriculum, but we mainly focused on the observation, monitoring and stimulation of children's activity, beneficiaries of cognitive and motor education, starting from the idea that the two influence each other. During the practical movement activity lessons, by organising and carrying out exercises, simple games and application paths ensuring the learning of basic motor skills and the integration of the children in group activities, we also focused on movement and cognitive training. The research investigated how the practical activities included verbal repetition of subject-related words in order to learn, understand and use them. The teacher aimed for the young children to memorise and grasp the words learnt in the practical activities. The knowledge and understanding of the meaning of words and sentences, lesson by lesson, requires and determines the involvement of the teacher in their solving and expresses the extent to which the children included in the research assimilate the correct meaning of the words and accommodate to the requirements of the educational-instructional process. The assessment of the motor and cognitive progress recorded after a period of 4 months of training and integration into the educational system highlights the improvements achieved by the group of children and the activity efficiency at an early age.

2.4. Data analysis

For data interpretation, there were used arithmetic mean, standard deviation, maximum and minimum value, *T*-Student test and Cohen's *D* coefficient. According to Mishra et al. (2019), the student's *t* test is used to compare the means between two groups. Cohen (1988, pp. 77–82), pointed to effect sizes of the correlation coefficient; he explained that the effect size was small when ($0 \leq r \leq 0.29$) and medium when ($0.30 \leq r \leq 0.49$), and large when ($0.50 \leq r \leq 1.00$).

2.5. Research ethics

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Vasile Alecsandri University of Bacău (No. 39/ 10.10.2023). The informed consent of the families and the verbal consent of the children were requested to ensure the conduct of the research. Also, the agreement of the management of the school institution was obtained.

3. Results and discussion

3.1. Assessment of the physical development of preschoolers

The improved motor ability has positive effects on the somatic development and mainly on weight and height, and the assessment indicators were calculated initially and for the pre-test and post-test evaluations. In terms of somatic development (**Table 2**) the following aspects were observed. Regarding height, the children recorded an arithmetic mean of 1.08 m on the pre-test and 1.14 m on post-test, thus an increase of 6 cm; a standard deviation with pre-test value of 1.36 and a postest value of 1.67, highlighting a slight decrease in the homogeneity of the group of children. A maximum value of 1.20 m on pre-test and 1.25 m on post-test assessment, therefore an increase of 5 cm and a minimum value of 0.98 m on pre-test and 1.06 m on post-test, hence an increase of 8 cm.

Table 2. Results of the somatic development and cognitive skills of 4–5-year-old children.

Crt. No.	In.	**Somatic development indicators**						**Cognitive development tests**					
		Height (m)			**Weight (kg)**			**T1**			**T2**		
		PR	**PO**	**Diff.**	**PR**	**PO**	**Diff.**	**PR**	**PO**	**Diff.**	**PR**	**PO**	**Diff.**
1	IP	1.00	1.06	0.06	16.20	18.30	2.10	1	2	1	1	2	1
2	TA	1.07	1.10	0.03	18.20	19.80	1.60	2	3	1	2	3	1
3	PS	1.12	1.19	0.07	22.80	27.00	4.20	1	2	1	1	2	1
4	PS	1.07	1.13	0.06	16.30	17.50	1.20	1	3	2	1	2	1
5	FI	1.10	1.16	0.06	23.00	26.70	3.70	2	3	1	2	3	1
6	ID	1.00	1.06	0.06	17.50	19.70	2.20	2	2	0	2	2	0
7	LM	1.10	1.15	0.15	21.30	23.50	2.20	1	2	1	1	2	1
8	GB	1.00	1.05	0.05	21.00	23.00	2.00	2	3	1	2	3	1
9	IA	1.20	1.25	0.05	20.00	22.00	2.00	3	3	0	2	3	1
10	PD	1.20	1.24	0.04	19.50	22.00	2.50	2	3	1	2	3	1
11	BL	1.10	1.13	0.03	18.60	20.50	1.90	1	2	1	1	2	1
12	DA	1.03	1.08	0.05	15.00	17.00	2.00	2	3	1	2	3	1
13	DM	1.03	1.07	0.04	15.70	18.00	2.30	1	3	2	1	3	2
14	DG	1.14	1.16	0.02	18.00	19.00	1.00	2	2	0	2	2	0
15	IC	1.07	1.08	0.01	17.50	19.00	1.50	3	3	0	3	3	0
16	BS	1.05	1.15	0.10	23.00	25.00	2.00	1	2	1	1	2	1
17	AS	0.98	1.08	0.10	20.00	24.00	4.00	2	3	1	2	3	1
18	TA	1.10	1.25	0.15	19.00	22.00	3.00	3	3	0	2	3	1
19	ZI	1.15	1.24	0.09	20.50	22.00	1.50	2	3	1	2	3	1
20	SC	1.13	1.20	0.07	22.30	27.20	4.90	1	2	1	2	2	0
M.		1.08	1.14	0.06	19.27	21.66	2.39	1.75	2.60	0.85	1.70	2.55	0.85
V. max.		1.20	1.25	0.15	23	27.2	4.9	3	3	2	3	3	2
V. min.		0.98	1.06	0.01	15.00	17.00	1.00	1	2	0	1	2	0
St. dev.		1.36	1.67	0.52	0.65	0.98	0.41	1.92	2.05	1.01	2.73	2.61	1.58

Crt. no. = current number, In = initials, H = subjects' height, W = weight, T1 = "Say the opposite word" Test, T2 = "Finish the sentence starting from the given word" Test, PR = pre-test, PO = post-test, Diff. = difference, *M* = mean, V. max. = maximum value, V. min. = minimum value, St. dev. = standard deviation.

Referring to weight, the children had an arithmetic mean of 19.27 kg on pre-test and 21.66 kg at the post-test, thus an increase of 2.39 kg. A standard deviation with an initial value of 0.65 and a final value of 0.98 suggesting a slight decrease in the homogeneity of the group of children. A maximum value of 23 kg on pre-test and 27.2 kg at post-test assessment, therefore an increase of 4.9 kg and a minimum value of 15 kg on the pre-test and 17.00 kg on the post-test, therefore an increase of 2 kg. After the age of 4 the annual height growth rate is 5 cm–7 cm per year", and the weight increase registered an average of 2.29 kg, valeus between which the evolution of the analyzed children's rezultats also falls.

According to the results recorded in the *T*-Student test regarding height, it can be seen that the results from the pre-test indicate a value of M = 1.082 and SD = 0.064, and the data from the post-test show a value of M = 1.141 and SD= 0.068 (**Table 3**), with. The values of $t = -8.370$ and $p < 0.001$, indicate a good statistical significance of the results, and the values of the Cohen's D coefficient (D = 0.893) show a large effect of the evolution over the time period.

The statistical data from the T-Student test, with reference to weight (**Table 3**), it is observed that in the pre-test stage, M = 19.27, SD = 2.421 and in the post-test phase, M = 21.66, SD = 3.120. The results indicate a good statistical significance of the results (t = 10.206, $p < 0.001$). Cohen's D coefficient values ($D = -0.835$) indicate a major effect of the intervention.

Table 3. Results of the *T*-Student test and Cohen's *D* coefficient regarding the physical development.

Statistical indicators	**Height**		**Weight**	
	H_PR	**H_PO**	**W_PR**	**W_PO**
Mean	1.082	1.141	19.27	21.66
Standard deviation	0.064	0.068	2.491	3.190
Student's test	$T = -8.370$		$T = -10.206$	
P* value	$P < 0.001$		$P < 0.001$	
Cohen's D	$D = -0.893$		$D = -0.835$	

* Results pre-test and post testing by applying the student's dependent t-test. A significant difference exists between the two tests if $p < 0.05$.
Legend: CDT1_PR = pre-test value for cognitive development test 1, CDT1_PO = post-test value for cognitive development test 1, CDT2_PR = pre-test value for cognitive development test 2, CDT2_PO = post-test value for cognitive development test 2.

3.2. Measuring the cognitive development of preschoolers

The results presented in **Table 2** show that the arithmetic mean recorded a value of 1.75 points in pre-test and 2.60 points in post-test, thus an improvement of 0.85 points. A standard deviation with a pre-test value of 1.95 and post-test of 2.05, highlighting a slight decrease in the homogeneity of the group. The maximum value is 3 points in both the pre-test and post-tests, and the minimum value is 1 point in pre-test and 2 points in post-test assessment.

The results from **Table 4** show that in pre-test, 8 children out of 20 require support for at most 4 words, 9 children out of 20 require support for at most 2 words and 3 children out of 20 do not require support for at most 5 words, and in post-test, no child out of 20 does not require support for at most 4 words, 8 children out of 20 require support for at most 2 words and 12 children out of 20 do not require support for at most 5 words. As it can be seen in **Table 4** and **Figure 1**, at the end of the experiment**,** the children improved their cognitive ability.

Table 4. Results of the development of cognitive ability of 4–5-year-old children.

Assessment requirements	**Cognitive development assessment tests**							
	Test 1				**Test 2**			
	PR	**%**	**PO**	**%**	**PR**	**%**	**PO**	**%**
Requires support for up to 4 words/4 sentences.	8	40	0	0	7	35	0	0
Requires support at most 2 words/2 sentences.	9	45	8	40	12	60	9	45
No help with pronunciation 5 words/5 sentences	3	15	12	60	1	5	11	55
Total answers	20	100%	20	100%	20	100%	20	100%

*T1 = "Say the opposite word" test, T2 = "Finish the sentence starting from the given word" test, PR = pre-test, PO = post-test, % = percentage.

Figure 1. Graphical representation of children's answers to Test 1 "Say the opposite word".

The results obtained in "Finish the sentence starting from the given word" test (**Table 2**) show that the arithmetic mean recorded a value of 1.75 points in pre-test and 2.60 points in postest stage, therefore an improvement of 0.85 points. A standard deviation with a pre-test value of 1.95 and a post-test value of 2.05, suggesting a good homogeneity of the group. The maximum value is 3 points in both pre-test and post-test; the minimum value is 1 point in the pre-test and 2 points in the post-test.

In the pre-test, 7 children out of 20 children require support for at most 4 sentences, 12 children out of 20 require support for at most 2 sentences and 1 child out of 20 children does not require support for all 5 sentences (**Table 4**). In post-test, no child out of 20 does not require support for at most 4 sentences, 9 children out of 20 require support for at most 2 sentences and 11 children out of 20 children do not require support for all 5 sentences. As it can be seen in **Figure 2**, the children had improved their cognitive ability at the end of the experiment.

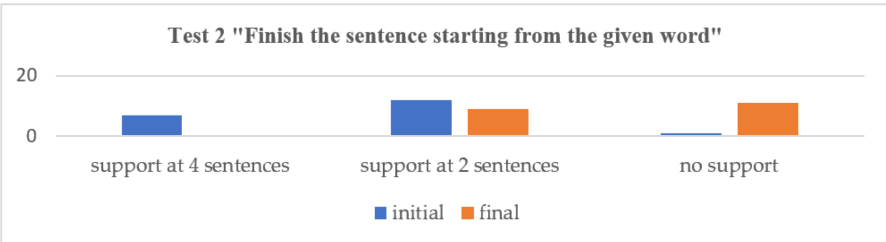

Figure 2. Graphical representation of the answers to Test 2—"Finish the sentence starting from the given word".

The results obtained with the help of the T-Student test in "Say the opposite word" Test (**Table 5**) indicate a good statistical significance ($t = -6.474$, $p < 0.001$). In pre-test, $M = 1.75$, and SD = 0.716 and in post-test $M = 2.60$, and SD = 0.502. Cohen's D coefficient values ($D = -1.374$) indicate a large effect of the intervention.

Table 5. Results of the *T*-Student test and Cohen's *D* coefficient regarding the cognitive development.

Statistical indicators	**Cognitive development test 1**		**Cognitive development test 2**	
	CDT1_PR	**CDT1_PO**	**CDT2_PR**	**CDT2_PO**
Mean	1.75	2.60	1.70	2.55
Standard deviation	0.716	0.502	0.571	0.510
Student's test	$T = -6.474$		$T = -7.768$	
P* value	$P < 0.001$		$P < 0.001$	
Cohen's *D*	$D = -1.374$		$D = -1.570$	

* Results in pre-test and post-test assessment by applying the student's dependent t-test. A significant difference exists between the two tests if $p < 0.05$.
Legend: CDT1_PR = pre-test value for cognitive development test 1, CDT1_PO = post-test value for cognitive development test 1, CDT2_PR = pre-test value for cognitive development test 2, CDT2_PO = post-test value for cognitive development test 2.

The data obtained for the test "Finish the sentence starting from the given word" (**Table 5**) with the help of the *T*-Student show that in the pre-test stage, $M = 1.70$, SD = 0.571, and in the post-test phase, $M = 2.55$, SD = 0.510. Therefore, there was a positive statistical significance of the results ($t = -7.768$, $p < 0.001$). Cohen's D coefficient values ($D = -1.570$) highlight a large effect of the intervention.

3.3. Assessment of motor skills of preschoolers

The development of motor skills (**Table 6**) was assessed by 4 tests: 5 m running with a standing start; throwing a 0.50 kg medicine ball at a distance; walking on a 5 m line and the labyrinth. Concerning the development of motor ability, the following aspects were observed.

In the 5 m running with a standing start, the children recorded an arithmetic mean of 6.24 s in pre-test and 4.74 s in post-test, an increase of 1.50 s; a standard deviation with an initial value of 6.24 and a final value of 4.74, suggesting a slight improvement in the homogeneity of the group of children; a maximum value of 8.4 s in pre-test and 7.6 s in post-test, so an improvement of 0.70 s and a minimum value of 4.0 s in pre-test and 2.0 s in post-test, thus an increase of 2 s. The data obtained for the "5m(s) run" test (**Table 5**), with the T-Student test, show that in the pre-test, $M= 6.238$, SD = 1.321 and in the post-test, $M= 4.735$, SD = 1.670. Therefore, the results indicate a positive statistical significance of the results ($t = 12.08$, $p < 0.001$). Cohen's D coefficient values ($D = 0.984$) indicate a large effect of the intervention.

Related to their distance throwing of a 0.50 kg medicine ball, the children had an arithmetic mean of 2.40 m at baseline and 3.15 m at post-test, thus an increase of 0.77 m; a standard deviation with a baseline value of 2.20 and a final value of 3.14, suggesting a slight regression in the homogeneity of the group of children; a maximum value of 3.20 m at pre-test and 5.00 m at post-test, thus an improvement of 1.80 m, and a minimum value of 1.30 m at pre-test and 1.80 m at post-test, thus an increase of 0.50 m. The results obtained in the test "Throwing the ball (m)" (**Table 5**), with the help of the *T*-Student test, demonstrate that in the pre-test stage, M = 2.395, SD = 0.650, and in the post-test phase, M = 3.135, SD = 0.980). There was a positive statistical significance of the results (t = 6.620, p < 0.001). Cohen's D coefficient values (D = −0.889) show a large effect of the intervention.

Table 6. Results of the evaluation of motor skills of 4–5-year-old children.

No.	**In.**	**5 m running (s)**			**0.50 kg ball throwing (m)**			**Walking on a 5 m line(s)**			**Labyrinth (s)**		
		PR	**PO**	**Diff.**	**PR**	**PO**	**Diff.**	**PR**	**PO**	**Diff.**	**PR**	**PO**	**Diff.**
1	IP	6.00	4.00	2.00	1.50	2.00	0.50	10.00	7.00	3.00	15.00	12.00	3.00
2	TA	4.56	2.00	2.00	3.00	5.00	2.00	9.00	5.00	4.00	12.00	10.00	2.00
3	PS	6.11	4.80	1.20	2.20	2.90	0.70	11.00	10.00	1.00	11.50	10.50	0.50
4	PS	6.50	4.50	2.00	2.00	1.80	0.20	9.90	9.50	0.40	16.00	10.00	6.00
5	FI	5.00	3.90	1.10	3.20	3.90	0.70	11.50	9.00	2.00	13.30	11.30	2.00
6	ID	7.90	6.90	1.00	2.40	2.90	0.50	8.20	7.00	0.80	12.00	10.50	1.50
7	LM	5.00	3.50	1.50	2.30	3.00	0.70	12.00	10.00	2.00	12.00	11.00	1.00
8	GB	5.50	3.50	2.00	3.20	3.80	0.60	9.00	7.00	2.00	11.90	9.90	2.00
9	IA	8.20	7.20	1.00	1.50	2.00	0.50	13.00	10.00	3.00	18.50	17.00	1.00
10	PD	5.00	4.00	1.00	2.90	3.50	0.60	12.00	10.00	2.00	15.00	13.50	1.50
11	BL	7.80	5.80	2.00	3.10	4.20	1.10	10.00	7.00	3.00	16.00	14.00	2.00
12	DA	4.50	3.50	1.00	3.00	4.00	1.00	8.00	7.50	0.50	10.00	9.00	1.00
13	DM	8.00	7.00	1.00	1.90	2.90	1.00	13.00	11.50	1.50	19.00	17.00	2.00
14	DG	4.50	2.50	2.00	3.00	4.50	1.50	7.00	5.00	2.00	11.00	9.00	2.00
15	IC	6.00	4.00	2.00	2.70	3.70	1.00	9.00	8.00	1.00	14.00	13.00	1.00
16	BS	8.40	7.60	0.80	1.30	1.90	0.60	14.00	13.00	1.00	17.00	12.00	5.00
17	AS	5.70	4.70	1.00	2.00	2.90	0.90	10.00	9.00	1.00	16.00	13.00	3.00
18	TA	5.60	3.40	2.20	3.10	3.90	0.80	9.10	7.00	1.90	11.70	9.70	2.00
19	ZI	8.10	7.30	0.80	1.50	2.10	0.60	12.90	10.10	2.80	18.30	17.10	1.20
20	SC	6.40	4.60	1.80	2.10	1.80	0.30	9.90	9.40	0.50	15.90	10.10	5.80
M		6.24	4.74	1.47	2.40	3.14	0.79	10.43	8.60	1.77	14.31	11.98	2.28
V. max.		8.40	7.60	2.20	3.20	5.00	2.00	14.00	13.00	4.00	19.00	17.10	6.00
V. min.		4.00	2.00	0.80	1.30	1.80	0.20	7.00	5.00	0.40	10.00	9.00	1.00
St. Dev.		1.36	1.67	0.52	0.65	0.98	0.41	1.92	2.05	1.01	2.73	2.61	1.58

Legend: Crt. no. = current number, 5 m running, ball throwing, walking on a 5 m line, labyrinth, In = initials, PR = pre-test, PO = post test, Diff. = difference, M = mean, V. max. = maximum value, V. min. = minimum value, St. dev.= standard deviation.

The children walked on a 5 m line with an arithmetic mean of 10.43 s in pre-test and 8.60 s in post-test, an increase of 1.83 s. A standard deviation with an initial value of 1.92 and a final value of 2.05 suggesting a slight decrease in the homogeneity of the group of children. Also, a maximum value of 14.00 s in pre-test and 13.00 s in post-test. Thus, an improvement of 1.00 s and a minimum value of 7.00 s in pre-test assessment and 5.00 s in postest assessment, an increase of 2.00 s. The results obtained with the help of the *T*-Student test in "Walking on a 5 m (m) line" (**Table 5**), with the T-Student test indicate a positive statistical significance (t =

8.11, $p < 0.001$). In pre-test stage, $M = 10.42$, SD = 1.921 and in postest stage, $M = 8.60$, SD = 2.050. The Cohen's *D* coefficient values ($D = -0.868$) highlight a large effect of the instructive-educational intervention.

Related to the labyrinth, the children recorded an arithmetic mean of 14.31 s at pre-test and 11.98 s at post-test, thus an increase of 2.13 s. A standard deviation with a pre-test value of 2.73 and a postest value of 2.61 indicate a slight improvement in the homogeneity of the group of children. A maximum value of 19.00 s in pre-test test and 17.10 s in postest test, thus an improvement of 1.9 s and a minimum value of 10.00 s in the pre-test assessment and 9.00 s in postest assessment, therefore an increase of 1.00 s.

The results obtained with the help of the the *T*-Student test in the "Labyrinth (s)" (**Table 7**), indicate a positive statistical significance of the results, ($t = 6.77$, $p < 0.001$). It is observed that in pre-test stage $M = 14.30$, SD= 2.733 and in post-test stage, $M = 11.98$, SD = 2.611. The Cohen's *D* coefficient values ($D = -0.916$) highlight a large effect of the intervention.

Table 7. Results of the *T*-Student test and Cohen's *D* coefficient regarding the motor development.

	5m running (s)		**0.50 kg ball throwing (m)**		**Walking on a 5m line (s)**		**Labyrinth (s)**	
	R5_PR	**R5_PO**	**TB_PR**	**TB_PO**	**W5_PR**	**W51_PO**	**L_PR**	**L_PO**
Mean	6.238	4.735	2.395	3.135	10.42	8.60	14.30	11.98
Standard deviation	1.361	1.670	0.650	0.980	1.921	2.050	2.733	2.611
Student's test	12.08		−6.620		8.11		6.77	
*P** value	$P < 0.001$		$P < 0.001$		$P < 0.001$		$P < 0.001$	
Cohen's *D*	$D = 0.984$		$D = -0.889$		$D = 0.916$		$D = 0.868$	

* Results in the pre-test and postest testing by applying the student's dependent t-test. A significant difference exists between the two tests if $p < 0.05$.
Legend: R5_PR = 5m running pre-test values, R5_F = 5m running post-test values, TB_PR = ball throwing pre-test values, TB_PO = ball throwing postest values, W5_PR = walking on a 5 m line pre-test values, W5_PO = walking on a 5 m line postest values, L_PR = labyrinth pre-test values, L_PO = labyrinth postest values.

4. Discussion

Based on the analysis related to motor skill assessment, the arithmetic means of the four events improved as follows: by 1.47 s in the 5 m running, by 0.79 m in the distance throwing of a 0.50 kg medicine ball, by 1.77 s in the 5 m line walking and by 2.28 s in the labyrinth. According to the research conducted by Roth et al. (2015), it is shown that an intervention with appropriate physical activity in preschool children can improve motor performance. Escolano-Pérez et al. (2020) point out that fine motor skills are quite flexible in early childhood, which allows physical education teachers to intervene in this direction. Carrying out practical physical education activities contributes to the development of motor ability, which is influenced by the increase in strength, about which (Mačak et al., 2022), following an experiment, say that after 6 months of a daily exercise programme, an improvement in muscle strength was found in preschool children compared to those peers allocated in the control group. No significant differences were found between the groups in the other fitness components analysed. Taking into consideration that the educational-instructional process at the preschool level is the basis for shaping human personality and this part of the child's development requires special attention, we believe that in parallel with learning different ways of movement, emphasis should be placed on retaining specific information, thus on the cognitive aspects of learning. The use of two simple tests, by means of which we assessed the children's ability to memorise and communicate theoretical information, is a real technique to emphasise the efficiency of practising physical exercises from an early age in the cognitive development of students.

"Increased physical activity has significant beneficial effects on motor skills and cognitive process (Zeng et al., 2017), functionality judged by the motor and verbal responses. The fact that in the "Say the opposite word" Test and in the "Finish the sentence starting from the given word" Test, in pre-test phase, the percentage of children who did not need any help was 15% and 5% respectively, and in post-test evaluation it reached 60% and 55% respectively, justifies us to consider that at the end of the experiment the children improved their cognitive ability. This idea was also emphasised by Timmons et al. (2007), claiming that in the early years "the nature of the physical activity required causes healthy physical, cognitive, emotional and social development if particular emphasis is placed on the interaction between physical activity and the acquisition of motor skills". "Practising physical exercise contributes to the ideal shaping of bone and muscle tissues, ensuring possible beneficial effects throughout life" (Alves and Alves, 2019), when performed moderately from an early age. "Children's success or failure can be explained by the nature and action of the factors involved in the organisation and management of the activity" (Rață and Rață, 2018, p. 31) of training but also by the hereditary predispositions.

After analysing and interpreting the recorded results, it was found that a well-organised activity in which well-specified aspects are followed up improves children's behaviour. The first hypothesis according to which the implementation during the 24 lessons of physical activity of a set of exercises and games aiming at teaching movement actions leads to an improvement of the children's motor skills was confirmed. The confirmation of this hypothesis is supported by the fact that in the four tests of motor ability assessment the p-values < 0.001 calculated by the student's test show a positive statistical significance. The Cohen's D coefficient values by which we assessed the size effect ranging from 0.868 to 0.984 show a great influence. The second hypothesis according to which the performance during 24 lessons of physical activity of a set of exercises and games aiming at learning movement actions in parallel with the learning of specific information produces an improvement of children's cognitive abilities was confirmed. The confirmation of this hypothesis is supported by the fact that in the two tests of cognitive ability assessment the values of $p < 0.001$ calculated by Student's test show a positive statistical significance. The values of Cohen's D coefficient by which we assessed the size effect ranging from 0.868 to 0.984, demonstrate a great influence. These values demonstrate a great influence, but also a concordance between the motor and cognitive development in pre-schoolers resulting from practicing physical exercises, games and using in parallel with practicing the answers given by the children to the teacher's questions. The results of the experimental research reinforce the findings of the systematic analysis carried out by Jylänki et al. (2022), as the majority (71%) of the included studies demonstrated the beneficial effects of the intervention on the development of cognitive skills.

5. Conclusion

The progress in all four motor ability assessment tests and in the cognitive ability assessment tests supports the efficiency of performing motor activities at the age of 4–5 years. After analysing and interpreting the recorded results, it was found that a well-organised activity in which well specified steps are followed can improve children's behaviour. We believe that at the pre-school age of 4–5 years it is very important to develop the children's motor skills, to get them used to playing, to the need for movement and harmonious physical development, to the need for competition and affirmation, all requiring attention and organisation. Future studies on this topic may provide relevant information for the fostering and establishment of an objective assessment to highlight the connection between both motor and cognitive expression abilities in children in the pre-school education.

Limitations and implications of the research

The limitation of the research is given by the small number of children (20), as we wanted to carry out a confirmatory experiment, to verify the evaluation strategy, which is not found in the Curriculum documents for early education in Romania, nor in the assessment standards. Obviously, the sample could have been larger, but we would have had to have the same circumstances for performing the activities and strategies, methods and contents used by the teachers, which is difficult but not impossible. A larger study with a control group will be conducted to assess the specific impact of the intervention by comparing outcomes.

In order to give consistency to early education regarding the motor and cognitive side, we intend to, together with the Bacău School Inspectorate, include this method of assessment in the entire county and extend it in an improved way to the age of 5–6. In the future, we consider it possible to expand to the entire country.

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References

Albu C, Albu A, Vlad TL, Iacob I. (2006). Psihomotricitatea [Psychomotor activity]. European Institute Publishing House.

Alesi M, Bianco A, Luppina G, Pepi A. (2016). Improving Children's coordinative skills and executive functions: the effects of a football exercice program. Perceptual and Motor Skills. 122 (1): 27-46. doi; 10.1177/0031512515627527.

Alves JG, Alves GV. (2019). Effects of physical activity on children's growth. Efeitos da atividade fisica sobre o crescimento de crianças crianças. Jornal de Pediatria. 95 (Supplement 1): 72-78. https://doi.org/10.1016/j.jped.2018.11.003.

Ansuya, Nayak BS, Unnikrishnan B, Shashidhara YN, Mundkur SC. (2023). Effect of nutrition intervention on cognitive development among malnourished preschool children: randomized controlled trial. Scientific Reports. 13: 10636. doi.org/10.1038/s41598-023-36841-7.

Bryant LM, Duncan RJ, Schmitt SA. (2020). The Cognitive benefits of participating in structured sport for preschoolers. Early Education and Development. 32(5): 729-740. Doi:10.1080/10409289.2020.1799619.

Carson V, Lee E-Y, Hewitt L, Jennings C, Hunter S, Kuzik N, Stearns JA, Unrau SP, Poitras VJ, Gray C, Adamo KB, Janssen I, Okely AD, Spence JC, Timmons BW, Sampson M, Tremblay MS. (2017). Systematic review of the relationships between physical activity and health indicators in the early years (0-4 years). BMC Public Health. 17: 854. Doi:10.1186/s12889-017-4860-0.

Cameron CE, Cottone EA, Murrah WM, Grissmer DW. (2016). How are motor skills linked to children's school performance and academic achievement? Child Development Perspectives. 10: 93–98. DOI: 10.1111/cdep.12168.

Cheung WC, Ostrosky MM, Yang H-W, Akamoglu Y, Favazza PC, Aronson-Ensign K. (2019). Merging Motor and Cognitive Development: There's So Much to Learn While Being Physically Active!. PALAESTRA. 33(3): 48-54.

Čoh, M. (2020). Motor and Intellectual Development in Children: A Review. Facta Universitatis. 18(3): 515-523, doi.org/10.22190/FUPES200918049C.

Cohen J. (1988). Statistical power analysis for the behavioral sciences, 2nd ed. Lawrence Erlbaum Associates.

Crova C, Struzzolino I, Marchetti R, Macsi I, Vannozzi G, Forte R, Pesce C. (2014). Cognitively challenging Phsical activity benefits executive funcțion in overweight childern. Journal of sports sciences. 32(3): 201-211. Doi:10.1080/02640414.2013.828849.

Djordjic V, Tubić T, Jaksic D. (2016). The Relationship between Physical, Motor, and Intellectual Development of Preschool Children. Procedia - Social and Behavioral Sciences. 233: 3-7. DOI: 10.1016/j.sbspro.2016.10.114.

Duncan G.J, Dowsett CJ, Claessens A, Magnuson K, Huston AC, Klebanov P, Sexton H. (2007). School readiness and later achievement. Developmental Psychology. 43(6): 1–31. doi: 10.1037/0012-1649.43.6.1428.

Escolano-Pérez E, Herrero-Nivela ML, Losada LJ. (2020). Association between preschoolers' specific fine (but not gross) motor skills and later Academic competencies: educational implications. Frontiers in Psihology. 11: 1044. https://doi.org/10.3389/fpsyg.2020.01044.

Fisher A, Boyle JM, Paton JY, Tomporowsk P, Watson C, McColl JH, Reilly JJ. (2011). Effests of physical education interevention on cognitive function in young children: randomized controlled pilot study. BMC Padriatics. 11: 97. Doi:10.1186/1471-2431-11-97.

Gallahue DL, Ozman JC. (2002). Understanding motor development: infants, children, adolescents, adults. McGraw-Hill.

Gao Z, Zhang T, Stodden D. (2013). Children's physical activity levels and psychological correlates in interactive dance versus aerobic dance. Journal of Sport and Health science. 2(3): 146-151. Doi: 101016/j.jshs.2013.01.005.

Geng D, Zhang X, Shi J. (2015). The Development of Fine Motor Skills and its Relation to Cognitive Development in Young Children. Advances in Psychological Science. 23(2): 261-267. doi: 10.3724/SP.J.1042.2015.00261.

Gizzonio V, Bazzini MC, Marsella C, Papangelo P, Rizzolatti G, Fabbri-Destro M. (2022). Supporting preschoolers' cognitive development: Short- and mid-term effects of fluid reasoning, visuospatial, and motor training. Child Development. 93(1): 134-149. doi: 10.1111/cdev.13642.

Houwen S, Visser L, van der Putten A, Vlaskamp C. (2016). The interrelationships between motor, cognitive, and language development in children with and without intellectual and developmental disabilities. Research in Developmental Disabilities. 53-54(June-July): 19-31. DOI: 10.1016/j.ridd.2016.01.012.

Howie EK, Pate RR. (2012). Physical activity and academic achievement in children: A historical perspective. Journal of Sport and Health Science. 2(3): 160-169. Doi: 101016/j.jshs.2012.09.003.

Invernizzi P, Crotti M, Bosio A, Scurati R, Lovecchio N. (2018). Correlation between Cognitive Functions and Motor Coordination in Children with Different Cognitive Levels. Advances in Physical Education. 8: 98-115. doi: 10.4236/ape.2018.81011.

Iverson JM. (2010). Developing language in a developing body: The relationship between motor development and language development. Journal of Child Language. 37(2): 229–261. doi.org/10.1017/S0305000909990432.

Jena AK, Paul B. (2016). Cognitive Developmental Phenomena of Pre-School Children in Relation to Socio-Economic Status, Anthropometric Status, and Home Environmental Status. Journal on Educational Psychology. 10(2): 22-35.

Jia N, Zhang X, Wang X, Dong X, Zhou Y, Ding M. (2021). The Effects of Diverse Exercise on Cognition and Mental Health of Children Aged 5-6 Years: A Controlled Trial. Movement Science and Sport Psychology. 12.

doi.org/10.3389/fpsyg.2021.759351.

Jylänki P, Mbay T, Hakkarainen A, Sääkslahti A, Aunio P. (2022). The effects of motor skill and physical activity interventions on preschoolers' cognitive and academic skills: A systematic review. Preventive Medicine. 155: 106948, https://doi.org/10.1016/j.ypmed.2021.106948.

Kamijo K, Pontifex MB, O'Leary KC, Scudder MR, Wu C-T, Castelli DM, Hillman CH. (2011). The effects on an afterschool physical activity program on Working memory in preadolescent children. Developmental Science. 14(5): 1046-1058. Doi:1111/j.1467-7687.2011.01054.4.

Kwak L, Kremers SPJ, Bergman P, Ruiz JR, Rizo NS, Sjöström M. (2009). Associations between physical activity, fitness, and academic achievement. Journal of Pediatrics. 155(6): 19-24. doi: 10.2016/j.jpeds.2009,06,019.

Latorre Román PA, Mora López D, Fernández Sánchez M, Salas Sánchez J, Moriana Coronas F, García-Pinillos F. (2015). Test-retest reliability of a field-based physical fitness assessment for children aged 3-6 years. Nutricion Hospitalaria. 32(4): 1683-8. DOI:10.3305/nh.2015.32.4.9486.

Mačak D, Popović B, Babić N, Cadenas-Sanchez C, Madić DM, Trajković N. (2022). The effects of daily physical activity intervention on physical fitness in preschool children. Journal of Sports Sciences. 40(2): 146-155. https://doi.org/10.1080/02640414.2021.1978250.

Magallón S, Narbona J, Crespo-Eguílaz N. (2016). Acquisition of Motor and Cognitive Skills through Repetition in Typically Developing Children. PLoS ONE. 11(7): e0158684. https://doi.org/10.1371/journal.pone.0158684.

Martzog P, Stoeger H, Suggate S. (2019). Relations between Preschool Children's Fine Motor Skills and General Cognitive Abilities. Journal of Cognition and Development. 20(4): 443-465. DOI: 10.1080/15248372.2019.1607862.

Masuda R, Lanier P, Peisner-Feinberg E, Hashimoto HA. (2021). Quasi-Experimental Study of the Effects of Pre-Kindergarten Education on Pediatric Asthma. International Journal of Environmental Research and Public Health. 18(19): 10461. doi: 10.3390/ijerph181910461.

Messerli-Bürgy N, Kakebeeke T, Meyer A, Arhab A, Zysset A, Stülb K, Leeger-Aschmann CS, Schmutz EA, Kreemler S, Puder JJ, Munsch S, Jenni OG. (2021). Walking onset: a poor predictor for motor and cognitive skills in healthy preschool children. BMC Pediatrics. 21: 367. doi.org/10.1186/s12887-021-02828-4.

Mishra P, Singh U, Pandey CM, Mishra P, Pandey G. (2019). Application of student's t-test, analysis of variance, and covariance. Annals of Cardiac Anaesthesia. 22(4): 407-411. doi: 10.4103/aca.ACA_94_19.

Nugroho IH, Lestariningrum A, Usman J. (2021). Analysis of Motor and Cognitive Development in Early Childhood by Gender and Learning Styles Through Drawing and Coloring Activity. Jurnal Ilmiah Potensia. 6(2): 109–112. doi.org/10.33369/jip.6.2.109-108.

Øksendal E, Brandlistuen RE, Holte H, Wang MV. (2021). Associations between poor gross and fine motor skills in pre-school and peer victimization concurrently and longitudinally with follow-up in school age - results from a population-based study. British Journal of Educational Psychology. 92(2): e12464. https://doi.org/10.1111/bjep.12464.

Pesce C, Stodden DF, Lakes KD. (2021) Editorial: Physical Activity "Enrichment": A Joint Focus on Motor Competence, Hot and Cool Executive Functions. Frontiers in Psychology. 12: 658667. doi: 10.3389/fpsyg.2021.658667.

Rață BC, Rață G. (2018). Didactica educației fizice, la învățământul preşcolar şi primar [Didactics of physical education in preschool and primary education]. Discobolul Publishing House.

Riso EM, Mãgi K, Toplaan L, Jűrimãe J. (2019). Conceptual skills and verbal abilities were better in children aged six to seven years who were from more highly educated families and attended sports clubs. Acta Paediatrica. 108(9): 1624-1631. doi.org/101111/apa.14750.

Roth K, Kriemler S, Lehmacher W, Ruf KC, Graf C. (2015). Hebestreit, H. Effects of a physical activity intervention in preschool children. Medicine & Science in Sports & Exercise. 47(12): 2542-2551. doi: 10.1249/MSS.0000000000000703.

Sánchez-López M, Cavero-Redondo I, Álvarez-Bueno C, Ruiz-Hermosa A, Pozuelo-Carrascosa DP, Díez-Fernández A, Gutierrez-Díaz del Campo D, Pardo-Guijarro MJ, Martínez-Vizcaíno V. (2019). Impact of a multicomponent physical activity intervention on cognitive performance: The MOVI-KIDS study. Scandinavian Journal of Medicine & Science in Sports. 29(5): 766-775. https://doi.org/10.1111/sms.13383.

Sember V, Jurak G, Kovac M, Morrison SA, Starc G. (2020). Children's Physical Activity, Academic Performance, and Cognitive Functioning: A Systematic Review and Meta-Analysis. Frontiers in Public Health. 8:307. doi: 10.3389/fpubh.2020.00307.

Tarnoto N, Tentama F, Pranungsari D. (2019). Experimental Study Based on Role Play Method to Improve Social Skills for Pre-School Aged Children of Street. Humanities & Social Sciences Reviews. 7(3): 155-16. doi.org/10.18510/hssr.2019.7324.

Timmons BW, Naylor PJ, Karin A, Pfeiffer KA. (2007). Physical activity for preschool children how much and how? Applied Physiology, Nutrition and Metabolism. 32 (S2E): S122–S134. https://doi.org/10.1139/H07-112.

Tomporowski PD. (2003). Effects of acute bouts of exercise on cognition. ACTA PSYCHOL (AMST). 112: 297–324. doi: 10.1016/S0001-6918(02)00134-8.

Tomporowski PD, McCulliek B, Pendleton DM, Pesce C. (2015). Exercise and children's cognition: the role of exercise characteristics and a place for metacognition, Journal of Sport anh Health Science. 4(1): 47-55. doi.org.10.1016/j.jshs.2014.09.003.

Tortella P, Schembri R, Ceciliani A, Fumagalli GF. (2020). Dual role of scaffolding on motor-cognitive development in early childhood education. Journal of Human Sport and Exercise. 15(4proc): S1407-S1417. doi.org/10.14198/jhse.2020.15.Proc4.37.

Tramontano M, Argento O, Manocchio N, Piacentini C, Orejel Bustos AS, De Angelis S, Bossa M, Nocentini U. (2024). Dynamic Cognitive-Motor Training versus Cognitive Computer-Based Training in People with Multiple Sclerosis: A Preliminary Randomized Controlled Trial with 2-Month Follow-Up. J Clin Med. 13(9): 2664. doi: 10.3390/jcm13092664.

Ureña N, Fernández N, Cárdenas D, Madinabeitia I, Alarcón F. (2020). Acute effect of cognitive compromise during physical exercices on self-regulation in early childhood education. International Journal of Environmental Research and Public Health. 17(24): 9325. doi.org/10.3389/fpsyg.2020.01044.

van der Fels IM, te Wierike SC, Hartman E, Elferink-Gemser MT, Smith J, Visscher C. (2015). The relationship between motor skills and cognitive skills in 4- to 16-year-old typically developing children: A systematic review. Journal of Science and Medicine in Sport. 18(6): 697–703. DOI: 10.1016/j.jsams.2014.09.007.

Veldman SLC, Santos R, Jones RA, Sousa-Sá E, Okely AD. (2019). Associations between gross motor skills and cognitive development in toddlers. Early Human Development. 132:39-44. doi: 10.1016/j.earlhumdev.2019.04.005.

Vicol M-I, Gavriluț M-L, Mâță L. (2024). A Quasi-Experimental Study on the Development of Creative Writing Skills in Primary School Students. Education Sciences, 14: 91. https://doi.org/10.3390/educsci14010091.

Westendorp M, Hartman E, Houwen S, Smith J, Visscher C. (2011). The relationship between gross motor skills and academic achievement in children with learning disabilities. Research in Developmental Disabilities. 32: 2773–2779. DOI: 10.1016/j.ridd.2011.05.032.

Williams RA, Cooper SB, Dring KJ, Morris JG, Sunderland C, Nevill ME. (2020). Effect of football activity and physical fitness of information processing, inhibitory control and working memory in adolescents. BMC Public Health. 1398. Doi:10.1186//s12889-020-09484-w.

Yiğit-Gençten V. & Aydemir F. (2023). An investigation of the social-emotional, language and self-care outcomes of the 2013 pre-school education program in terms of nature-based learning. Trakya Journal of Education. 13(1): 652-668.

Yiğit-Gençten V, Gultekin M, Aydemir, F. (2024). Exploring the hidden canvas: Conceptualisations of nature in early years curricula and standard documents in Turkey. The Curriculum Journal. 35(3): 1-23.

Zeng N, Ayyub M, Sun H, Wen X, Xiang P, Gao Z. (2017). Effects of physical activity on motor skills and cognitive development in early childhood. Biomed Research International. 1: 1-13. doi.org/10.1155/2017/2760716.