Effects of motor intervention programs on children's academic skills: a systematic review

Efectos de los programas de intervención motora en las habilidades académicas de los niños: una revisión sistemática

Authors

Ricardo de Almeida Pimenta [1]
Raphael Teixeira de Almeida Ramos [2]
Lisiane Schilling Poeta [1]
Fabiane Frota da Rocha Morgado [2]

[1] Federal University of Santa Catarina (Brazil)
[2] Federal Rural University of Rio de Janeiro (Brazil)

Corresponding author:
Ricardo de Almeida Pimenta
ricardo.pimenta@ufsc.br

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Abstract

Introduction: Child motor development is characterized by acquiring a spectrum of motor skills that enables children to control their bodies in different postures, explore the environment, and manipulate objects. Especially at the beginning of the schooling process, there is a significant increase in these skills linked to the development of body perception, space, and time, which constitute basic components of both motor learning and academic activities.
Objective: The aim was to identify and describe, based on scientific literature, the effects of motor intervention programs on children's academic skills.
Methodology: This systematic literature review is registered under protocol CRD42020203996 in PROSPERO. Studies were selected using the following databases: Scopus, Web of Science, SciELO, SPORTDiscus (EBSCOhost), and PubMed (MedLine). The selection process followed the PRISMA method. This review included intervention studies of clinical trials and randomized controlled trials with children aged 6 to 12 years old published in the last 10 years (2014 to 2024).
Results: A total of 2,819 publications were identified, and after applying the inclusion and exclusion criteria, 8 articles were selected.
Discussion: It was possible to observe the fundamental role of motor interventions in both motor skills and academic learning. Also, it was observed an impact on the executive function variables associated with academic learning.
Conclusions: It was observed that motor intervention programs can play a facilitating role in the academic development of children, with positive impacts, especially concerning reading, writing, and mathematics.

Keywords

Academic skills; children; learning; motor intervention; motor skills.

Resumen

Introducción: El desarrollo motor infantil se caracteriza por la adquisición de un espectro de habilidades motoras que les permite controlar su cuerpo en diferentes posturas, explorar el entorno y manipular objetos. Especialmente al inicio de la escolarización, se observa un aumento significativo de estas habilidades, vinculado al desarrollo de la percepción corporal, del espacio y del tiempo, componentes básicos tanto del aprendizaje motor como de las actividades académicas.
Objetivo: El objetivo fue identificar y describir, con base en la literatura científica, los efectos de los programas de intervención motora en las habilidades académicas de los niños.
Metodología: Esta revisión sistemática de la literatura está registrada bajo el protocolo CRD42020203996 en PROSPERO. Los estudios se seleccionaron utilizando las siguientes bases de datos: Scopus, Web of Science, SciELO, SPORTDiscus (EBSCOhost) y PubMed (MedLine). El proceso de selección siguió el método PRISMA. Esta revisión incluyó estudios de intervención de ensayos clínicos y ensayos controlados aleatorizados con niños de 6 a 12 años, publicados en los últimos 10 años (2014 a 2024).
Resultados: Se identificaron 2819 publicaciones y, tras aplicar los criterios de inclusión y exclusión, se seleccionaron 8 artículos.
Discusión: Se observó el papel fundamental de las intervenciones motoras tanto en las habilidades motoras como en el aprendizaje académico. Asimismo, se observó un impacto en las variables de la función ejecutiva asociadas al aprendizaje académico.
Conclusiones: Se observó que los programas de intervención motora pueden desempeñar un papel facilitador en el desarrollo académico de los niños, con impactos positivos, especialmente en la lectura, la escritura y las matemáticas.

Palabras clave

Aprendizaje; habilidades académicas; habilidades motoras; intervención motora; niños.

Introduction

Motor development is a continuous process of changes in functional capacities throughout life, as part of a sequential process that is related but not dependent on chronological age (Haywood & Getchell, 2009). It is characterized by the interaction between task requirements, individual biology, and environmental conditions and is inherent to social, intellectual, and emotional changes (Gallahue et al., 2013). Among the reasons for the growing interest in motor development knowledge is the parallel between motor and cognitive development, highlighting the close relationship between what a child can learn and what they can perform (Rosa Neto et al., 2010).

During childhood, particularly at the onset of schooling, motor skills increase linked to the development of body, space, and time perception, all essential for effective learning. The early years of education are crucial for children to develop motor skills and establish movement patterns that will later favor their participation in a variety of physical activities (Oñate Navarrete et al., 2021).

While fundamental movement patterns of locomotion, posture, and interaction with objects emerge in childhood, subsequent years channel continuous adaptive influences on movement patterns and the development of emerging motor skills (Newell, 2020). Motor development from age six is marked by the consolidation of the fundamental motor phase, with the transition to the specialized motor phase occurring at age seven (Gallahue et al., 2013). In association, the child develops more elaborate patterns of skills linked to advances in perceptual abilities concerning self, environment, and objects (Haywood & Getchell, 2009). Specifically, at six years old, the associations between motor development and academic skills become evident through learning to write, reading skills, and mathematical abilities (de Waal, 2019).

Westendorp et al. (2011), when evaluating children aged 7 to 12 years, found that children with learning difficulties scored lower in locomotion and broad object control tests compared to their typically developing peers, showing a specific relationship between reading and locomotor skills and a tendency for a relationship between mathematics and broad object control skills. In a literature review, Priyadi et al. (2024) found that fine motor skills affect literacy processes, including writing, play, and daily life skills related to writing in studies with children aged 5 to 13 years. Pieters et al. (2012) showed, in a study with forty-three 9-year-old children with Developmental Coordination Disorder (DCD), that those with motor difficulties tend to show academic failure related to underlying mathematical knowledge, such as memorization and numerical use in calculation procedures. Additionally, lower scores in motor domains represent, beyond an indication of motor delay, impairments in executive function components necessary for learning, such as attention and memory, as shown by Alloway and Archibald (2008) in a study with children aged 6 to 11 with DCD, who showed impairments in all four areas of memory function assessed (short-term verbal memory, verbal working memory, short-term visual-spatial memory, visual-spatial working memory). They may also be associated with specific neurodevelopmental disorders, such as Attention Deficit/Hyperactivity Disorder (ADHD; Goulardins et al., 2013). About 50% of children with Developmental Coordination Disorder also meet the criteria for attention disorders (Blank et al., 2012). According to Poeta and Rosa Neto (2007), children diagnosed with ADHD show low levels of spatial and temporal organization classification, as the tasks involve processes of location, orientation, visuospatial recognition, perception of distance, and speed. Executive functions, especially attention and memory, are essential for academic learning (Fernandes et al., 2016). In the school environment, executive functions are required, as situations presented in school demand solutions to proposed problems, planning, and adaptation to various situations to pursue new goals (Sartori et al., 2021).

Evaluating and monitoring children's motor development is essential to identify and track developmental delays and clarify instructional and intervention strategies. Additionally, the possibilities of errors in intervention programming are minimized, thus ensuring a concrete path between the individual's initial condition and the proposed educational objectives (Silveira et. al., 2006; Vieira et al., 2009). The study hypothesized that motor interventions positively affect the development of academic skills. Thus, based on the scientific literature, the aim was to verify the possible effects of motor intervention programs on reading, writing, and mathematical academic skills in children with or without developmental coordination disorders.

Method

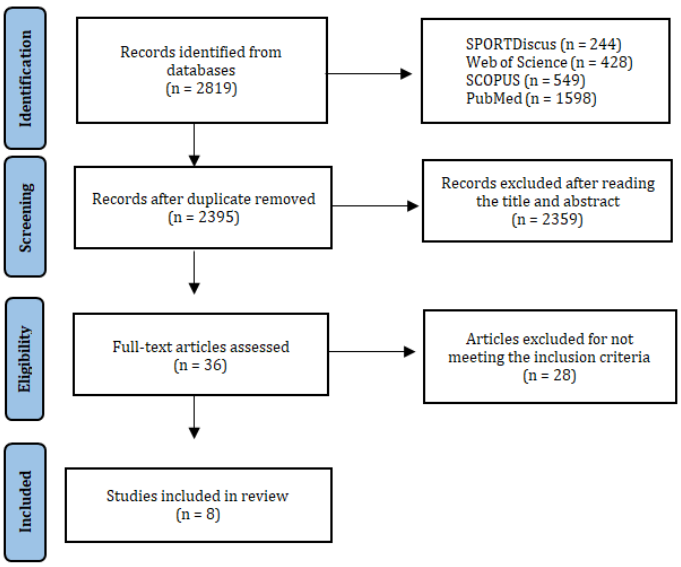
This systematic literature review is registered under protocol CRD42020203996 in the International Prospective Register of Systematic Reviews (PROSPERO). The PICOS strategy (Methley et al., 2014) was used to formulate the research problem and establish inclusion criteria. In this framework, the "population" (P) consists of children (ages 6–12), the "intervention" (I) includes motor intervention programs and/or physical activity programs, the "comparator" (C) refers to children who are not exposed to the motor intervention program and/or physical activity program, the "outcome" (O) focuses on evaluating the effectiveness of the motor intervention programs on academic skills, and the "study types" (S) are intervention studies (Clinical Trial and Randomized Controlled Trial).

Searching and Selecting Studies Procedures

The following online databases were used for the research and selection of studies: Scopus, Web of Science, SciELO, SPORTDiscus (EBSCOhost), and PubMed (MedLine). The descriptors used were: ("physical activity intervention" OR "motor skills intervention" OR "physical activity program" OR "motor program" OR "motor intervention" OR "motor development") AND (learning OR academic OR "academic achievement" OR "Specific Learning Disorder" OR "Learning Disabilities") AND (“child” OR “children”).

The research was conducted in June 2023 and updated in July 2024. The search results from each database were imported into the RAYYAN application (Ouzzani et al., 2016), where titles and abstracts were assessed by two independent reviewers (blind selection) based on eligibility criteria. A third reviewer addressed any discrepancies (Ouzzani et al., 2016). The selection process followed the PRISMA guidelines (Moher et al., 2009) as illustrated in the article selection flowchart shown in Figure 1.

Figure 1. PRISMA flowchart - Identification of studies via databases



Eligibility Criteria

This review included clinical trial and randomized controlled trial intervention studies involving children aged 6 to 12, conducted in the last decade, with literature available in Portuguese and English. The age range was defined based on the understanding that children older than six are in the literacy phase of their education, actively participating in formal reading and writing assessments. In mathematics, children begin to learn, recognize, and utilize the social functions of numbers, along with concepts in algebra, geometry, and measurement, which are typical of elementary education, distinguishing them

from earlier educational stages (Brasil, 2018). This age range also aligns with the Medical Subject Headings (MeSH) terms for children (Medical Subject Headings, 1999), underscoring the importance of a controlled vocabulary for uniformity and consistency in the indexing and cataloging of biomedical literature. The 10-year time frame aimed to include the most up-to-date research on the topic. However, review studies, books, and book chapters were excluded to focus exclusively on primary data.

Data analysis

All articles meeting the inclusion criteria were read in full to systematize and analyze the material. Summaries of their main information were then created, including authorship, publication year, methodological design, study focus, variables studied (independent and dependent variables), effects of the intervention, and conclusions (correlations between variables and conclusions about the effect of the intervention). The data were compiled into tables for study characterization and presented descriptively and analytically in this review. Suggestions from the studies regarding future research and the applicability of the results were also summarized and integrated.

Results

A total of 2,819 publications were initially identified, and after applying the inclusion and exclusion criteria, 8 articles were selected for this systematic review. The characterization data of the studies is presented according to the author/publication year, study objective, methodology, main results, and conclusions, as detailed in Table 1.

Table 1. Descriptive results for all 8 selected articles

Author/year	Objective	Intervention description	Results	Conclusion
Ghahramani et al. 2016	To explore the effects of physical activity on impulsivity control, attention, decision-making and motor functions in schoolchildren with high and low impulsivity	Sample n = 40 Age = 9 to 12 years (elementary school students). The sample represented the upper and lower end of the distribution of impulsivity scores. They were randomly assigned to training and control groups at both levels of impulsivity The physical activity program consisted of vigorous and moderate activities, 60 minutes, 3 times per week (54 sessions)	Impulsivity post-test scores decreased in the high (F=3.583, P=0.014, η^2= 0.314) and low impulsivity groups (F=5.687, P=0.11, η^2= 0.223). In addition, improvements were observed in attention and decision-making tests. Motor functions showed significant improvements for the low impulsivity group (F=6.68, P=0.0001, η^2= 0.623) and for the high impulsivity group (F=5.53, P=0.001, η^2= 0.514) compared to the control group	The physical activity program reduced impulsivity levels and, in addition, improved attention, decision-making and motor functions in students with different levels of impulsivity, especially those with low impulsivity
Hraste et al. 2018	To examine the effectiveness of an integrated mathematics/geometry and physical activity program specifically designed to enhance learning in fourth grade students	Sample n = 36 (Experimental group n = 19; Control group n = 17) Age = mean 10.36±0.55 The experimental group participated in the integrated teaching method of mathematics/geometry and physical activity. Each intervention lasted 45 minutes, and classes occurred over four weeks. The control group used traditional teaching methods	The results indicated that the group of children who participated in the intervention group were significantly more successful than the control group. The results show a statistically significant impact for the factor ($F_{1,36}$ = 5.051; P = 0.031; η_p^2 = 0.12) and the treatment factor ($F_{1,36}$ = 7.760; P = 0.008; η_p^2 = 0.177). The significant impact of the group factor points to the differences between the two groups (intervention and control)	The proposed integrated teaching method can be considered more effective than traditional methods for teaching mathematics and geometry based on motor tasks. Consequently, the results indicate the synergistic effects of the cognitive and motor components of the central nervous system, compared to the cognitive component alone
Vetter et al. 2018	To compare the effectiveness of a multiplication table teaching approach associated with aerobic activity with the traditional classroom approach	Sample n = 85 Age = mean 9.8±0.3 The intervention consisted of combining multiplication table activities and physical-motor activities in a combination of skills appropriate to the developmental stage, such	There were no significant improvements between the control and intervention groups in the multiplication table tests. However, the numbering condition showed significant improvements for the intervention group compared to the control group (Control Group: 0.7% (1.2%);	Although no significant improvements were observed between the intervention and control groups in multiplication table tests, positive results were observed in other mathematical areas and in physical abilities

		as running, jumping rope, walking and galloping. The control group was subjected to mathematical multiplication table games in the classroom. Interventions of 20 minutes were carried out, 3 times a week for 6 weeks.	Intervention Group: 5.3% (1.4%); ES = 0.42; 0.08 - 0.75; P < .03)	
García-Hermoso et al. 2019	To test a before-school physical activity intervention on academic performance, selective attention, concentration capacity, anthropometry, body composition and physical fitness parameters	Sample n = 170 (Intervention Group n = 100; Control Group n = 70) Age = 8 to 10 years Intervention program: Active-Start for 8 weeks, totaling 39 sessions before the start of the first class	No significant and active changes were found in attention and concentration ability. However, significant changes were observed in reading (0.63; 95% CI 0.49 to 0.77; ES = 0.83) and mathematics (0.49; 95% CI 0.32 to 0.66; ES = 0.60) performance	Implementing preschool motor programs, such as Active-Start, to improve cardiorespiratory fitness may benefit students' cognitive ability and academic success
Kashfi et al. 2019	To examine the effect of a motor intervention based on the attention, balance, and coordination (ABC) learning approach on motor proficiency and executive functions in children with learning disabilities	Sample n = 45 Age = 7 years Experimental Group "A" participated only in the motor intervention program. Children in Experimental Group "B" participated in a motor intervention program and simultaneously received regular educational services at centers focused on learning disabilities. The motor intervention consisted of 24 sessions, three times a week for eight weeks. Each session lasted approximately 55 minutes, based on the elements of attention, balance and coordination	The study found significant improvements in motor skills and executive functions of sustained attention, working memory, and planning and problem-solving skills in the intervention groups (p<.05). Improvements in some measures of executive function in Experimental Group "B" were only slightly better than in Experimental Group "A"	The findings highlight the interaction between cognitive and motor processes, bringing practical implications for professionals in the field in contact with children with learning disorders
Botha & Africa 2020	To investigate the effect a perceptual-motor intervention on the relationship between gross motor proficiency and letter knowledge in selected Grade 1 children	Sample n = 97 Age = 6 to 7 years The intervention focused on perceptual-motor skills (e.g., body and spatial awareness, laterality, and proprioception). In addition, the intervention incorporated different letters and shapes into gross motor activities with the goal of improving letter recognition and formation. The intervention lasted 12 weeks with 60-minute sessions	The study found a correlation between motor and literacy skills (p<0.01). In addition, the perceptual-motor intervention was effective in significantly improving reading and spelling skills (p<0.05). The main finding was the correlation between motor proficiency and spelling (r = 0.46)	The results show that motor development is essential for academic performance. Therefore, integrating movement into academic tasks is an effective way to promote motor and learning skills in 1st grade children
Chaddock-Heymanl et al. 2020	To examine the relationship between baseline brain network modularity (pre-intervention) and changes (post-intervention) in cognitive and academic performance in children who participated in an after-school physical activity intervention program	Children n = 150 (n = 78 Intervention Group; n = 72 Control Group) Age = 7 to 9 years Intervention program: "Fitness Improves Thinking in Kids 2" (with various developmentally appropriate physical activities in a non-competitive environment and with activities that integrate physical conditioning and motor skills practice). The intervention program lasted two hours after each school day for 150 days of	Children who participated in the after-school motor intervention showed greater modularity of brain networks predictive of improvements in executive processes (α = 0.260, t = 2.328, p = 0.023); cognitive efficiency (α = 0.390, t = 3.647, p < 0.001); mathematics performance (α = 0.347, t = 3.221, p = 0.002) compared to the control group.	The results indicate associations between brain organization, cognitive and academic performance, and lifestyle factors such as physical activity. The evidence suggests that brain network modularity predicts changes in cognitive function following an intervention

		the academic year (9 months)		
Huang et al. 2020	To examine the effects of acute aerobic exercise on sustained attention and discriminatory ability in children with and without learning disabilities	Children n = 100 (Control Group n = 49; Children with learning disabilities group n = 51) Age = mean 12.02 ± 0.81 (Group with learning disabilities) and 12.12 ± 0.78 (Control Group) Participants were randomly assigned to exercise and control groups. The intervention group underwent a 30-minute aerobic exercise session on a treadmill, while the control group watched a running-related video for 30 minutes	Both groups, with and without learning disabilities, who received the intervention obtained better scores for sustained attention in the post-test (all p<.001), with a greater effect (4.04 and 1.34). Significant results were also observed in the accuracy rate (determination ability) in the post-test t(49)=−10.72, p<.001 ES=1.53. In addition, the exercise groups with children with learning disabilities and with typical development obtained a better reaction time, while the control group showed no differences in reaction time	Improvements in sustained attention and discriminatory ability were observed in children with learning disabilities and children with typical development. However, these improvements were more pronounced in children with learning disabilities

Discussion

Aiming to identify and describe, based on scientific literature, the effects of motor intervention programs on children's academic skills, this systematic review identified eight articles highlighting significant impacts on reading, writing, and mathematics. The analysis considered the effects of various structured interventions, ranging from specifically motor-based skills (Vetter et al., 2018; Kashfi et al., 2019; Botha & Africa, 2020) to interventions focusing on physical activity programs that address motor variables (Ghahramani et al., 2016; Hraste et al., 2018; García-Hermoso et al., 2019; Chaddock-Heyman et al., 2020; Huang et al., 2020). For the analysis of academic skills variables, beyond specific tests, studies included tests for attention, concentration, and memory (Ghahramani et al., 2016; García-Hermoso et al., 2019; Kashfi et al., 2019), reading (García-Hermoso et al., 2019), writing (Botha & Africa, 2020), mathematics (Hraste et al., 2018; Vetter et al., 2018; Chaddock-Heyman et al., 2020), as well as assessments of academic performance through school grades. Additionally, the reviewed articles evaluate and point out the relationship between academic content and executive function components, focusing on attention and memory (Ghahramani et al., 2016; García-Hermoso et al., 2019; Chaddock-Heyman et al., 2020).

In response to the research objective, descriptive results indicate that reading and writing skills show significant improvements with the implementation of motor intervention programs. In this context, Botha and Africa (2020) provide evidence that motor development can relate to academic success, showing that a perceptual-motor intervention effectively improves fine and gross motor skills and reading and writing. This study incorporated letters and shapes in interventions targeting specific motor areas such as body schema, spatial orientation, laterality, and proprioception. Even in studies that do not focus exclusively on motor intervention, such as García-Hermoso et al. (2019), an improvement in academic performance associated with the intervention program was observed. The study based on a comprehensive physical-motor fitness program showed a positive impact on academic performance, specifically in reading and math performance, associated with enhanced cardiorespiratory fitness. This finding aligns with previous literature indicating that motor and physical fitness variables interact and mediate academic skills (Lopes et al., 2013).

Regarding mathematics skills, Hraste et al. (2018) indicate that physical-motor intervention programs integrated with the development of mathematical skills were helpful and efficient for teaching math and geometry content through motor tasks compared to traditional teaching methods. Considering that learning is a complex process and not merely about memorization, Hraste et al. (2018) highlight that incorporating movement enhances mathematical knowledge and supports academic performance.

Chaddock-Heyman et al. (2020) identified a link between brain network modularity and academic performance in motor task programs, revealing significant results in mathematics learning. These findings enhance the understanding of the connections between motor tasks and the development of mathematical skills, extending beyond mere motor specificity. Conversely, Vetter et al. (2018) did not observe

significant improvements in learning multiplication tables after a physical activity program focused on fundamental motor skills (e.g., running, jumping, walking, and galloping). Despite the lack of significant effects on multiplication table teaching, Vetter et al. (2018) noted improvements in numeration skills when comparing control and intervention groups. They emphasized the feasibility of the physical-active learning approach, with added potential benefits in aerobic capacity. Despite differences in the specificity of the mathematical domain across articles, which can be partially explained by variations in samples, interventions, and assessment methods (as described in Table 1), it is acceptable to admit that school problems associated with motor skills can extend to mathematics abilities.

According to Pieters et al. (2012), children aged 9 to 12 with Developmental Coordination Disorder exhibited problems in numerical fact retrieval and procedural calculation (involving both numerical system knowledge and mental calculation), experiencing difficulties in simple arithmetic and more complex mental calculation issues. As problem complexity increases, there is a greater demand for complex procedural knowledge, requiring more from executive function components such as attention and working memory (Pieters et al., 2012). Concerning learning-related executive function components, motor intervention programs positively impacted attention and memory. Through a motor intervention program, Kashif et al. (2019) demonstrated significant improvements in memory, attention, problem-solving, and planning abilities in children with learning disorders. It is supported by Ghahramani et al. (2016), who showed that physical activity affected controlling high and low impulsivity, decision-making, motor functions, and attention, concluding that the intervention program reduced impulsivity and improved attention. Executive functions are essential for school success as they allow mental flexibility, thinking before acting, handling new and unexpected challenges, inhibiting behaviors, and maintaining focus - constituting elements like reasoning, problem-solving, and action planning (Diamond, 2013).

The interaction between cognitive and motor processes is exemplified by Huang et al. (2020), who found that a physical-motor activity program led to enhancements in sustained attention among children with both learning difficulties and typical development. These results are corroborated by earlier research, such as that conducted by Kamijo et al. (2011), which identified a correlation between cardiorespiratory fitness and working memory performance. Following a post-class motor intervention, improvements were noted in both cardiorespiratory fitness and working memory improvements. As a result, school performance also benefits, given the direct association between working memory, sustained attention, and favorable learning outcomes. Cognitive skills and executive function components were evaluated in intervention programs with children with learning disorders (Kashfi et al., 2019; Huang et al., 2020). The studies reported improvements in attention, working memory, planning, and problem-solving skills, with more pronounced effects in children with learning difficulties (Huang et al., 2020). The observed results align with previous findings, indicating that children with learning difficulties exhibit lower performance in locomotion and object control, which are fundamental motor skills, compared to children with typical development. In the study conducted by Westendorp et al. (2011), a specific link between reading abilities and locomotor skills was identified, along with a tendency to find a correlation between mathematics performance and object control skills within the group of children facing learning difficulties. Furthermore, Visser et al. (2020) report that DCD and/or ADHD are associated with challenges in reading, writing, and mathematics, thus highlighting that children with DCD or ADHD encounter greater difficulties across all areas of learning than their peers.

In summary, the studies affirm that physical-motor intervention programs affect the relationship between motor skills and academic performance, especially in reading, writing, and mathematics, significantly yielding positive impacts on observed variables. The relationship between executive functions (memory and attention) and motor and academic skills development was also identified. Interventions showed that motor function stimulation significantly improved academic skills for children with learning disorders compared to children without such conditions. Similarly, motor function stimulation markedly enhanced academic skills in children with motor delays compared to those without any indication of such delays. Therefore, motor intervention programs can facilitate children's academic development, particularly concerning reading, writing, and mathematical skills.

Studies suggest that improvements are observed after four weeks, and interventions ranging from twenty minutes to an hour at least three times a week are sufficient to observe effects (Hraste et al., 2018; Vetter et al., 2018; Chaddock-Heyman et al., 2020). The types of interventions varied, but most

aimed to associate physical capacity and motor skills development (Ghahramani et al., 2016; Hraste et al., 2018; García-Hermoso et al., 2019; Huang et al., 2020; Chaddock-Heyman et al., 2020).

These conclusions have clinical and educational implications for physical education, reinforcing the relevance of early identification and intervention in children with motor delays and emphasizing motor intervention as an essential part of children's academic development. In terms of school physical education, this curricular component needs to offer children opportunities to engage in physical practices, especially those that work with overall coordination (running, jumping, dancing, etc.) alongside play and games, which, beyond expected content, closely relate to motor, cognitive, and socio-emotional development (Veintimilla et al., 2024). As a limitation, this investigation describes and points out the results found in the studies selected for this review without analyzing effect sizes in intervention comparisons to determine the differences among them hierarchically. Also, the variability of measurement and evaluation instruments between studies was not compared. Moreover, this study does not analyze the methodological quality of the studies reviewed despite the methodological rigor of the systematic review presented. Articles were selected in English and Portuguese, which, despite understanding the reach of the English language, may represent a limitation.

Conclusions

In conclusion, implementing programs that combine motor and academic tasks yields positive effects, suggesting a significant relationship between physical and motor activities and academic learning. However, the precise nature of this relationship remains unclear. The variation in scope and differences among programs indicates a crucial area for further exploration in future research, particularly in comparing variability in intervention intensities and durations. Despite these variations, all reviewed studies demonstrated that motor intervention programs positively impact academic performance, especially in reading and mathematics, primarily when motor and academic skills are associated. Moreover, enhancements in executive functions like memory and attention have been shown to correlate with academic performance. Future research should focus on assessing the cumulative effects of motor interventions over time and aim to differentiate outcomes in specific skills or functions, such as variations in mathematical abilities.

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References

Alloway, T. P., & Archibald, L. (2008). Working memory and learning in children with developmental coordination disorder and specific language impairment. *Journal of Learning Disabilities, 41*(3), 251-262. https://doi.org/10.1177/0022219408315815

Blank, R., Smits-Engelsman, B., Polatajko, H., Wilson, P., & European Academy for Childhood Disability (2012). European Academy for Childhood Disability (EACD): recommendations on the definition, diagnosis and intervention of developmental coordination disorder (long version). *Developmental Medicine and Child Neurology, 54*(1), 54–93. https://doi.org/10.1111/j.1469-8749.2011.04171.x

Botha, S., & Africa, E. K. (2020). The effect of a perceptual-motor intervention on the relationship between motor proficiency and letter knowledge. *Early Childhood Education Journal, 48*(6), 727-737. https://doi.org/10.1007/s10643-020-01034-8

Brasil. (2018). *Base Nacional Comum Curricular*. Ministério da Educação.

Chaddock-Heyman, L., Weng, T. B., Kienzler, C., Weisshappel, R., Drollette, E. S., Raine, L. B., Westfall, D. R., Kao, S. C., Baniqued, P., Castelli, D. M., Hillman, C. H., & Kramer, A. F. (2020). Brain network modularity predicts improvements in cognitive and scholastic performance in children involved

in a physical activity intervention. *Frontiers in Human Neuroscience, 14*, Article 346. https://doi.org/10.3389/fnhum.2020.00346

de Waal, E. (2019). Fundamental movement skills and academic performance of 5-to 6-year-old preschoolers. *Early Childhood Education Journal, 47*(4), 455-464. https://doi.org/10.1007/s10643-019-00936-6

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Fernandes, V. R., Ribeiro, M. L. S., Melo, T., de Tarso Maciel-Pinheiro, P., Guimarães, T. T., Araújo, N. B., Ribeiro, S., & Deslandes, A. C. (2016). Motor coordination correlates with academic achievement and cognitive function in children. *Frontiers in Psychology, 7*, Article 318. https://doi.org/10.3389/fpsyg.2016.00318

Gallahue, D. L., Ozmun, J. C., & Goodway, J. D. (2013). *Understanding motor development: babies, children, teenagers and adults*. AMGH Editora.

García-Hermoso, A., Hormazábal-Aguayo, I., Fernández-Vergara, O., González-Calderón, N., Russell-Guzmán, J., Vicencio-Rojas, F., Chacana-Cañas, C., & Ramírez-Vélez, R. (2020). A before-school physical activity intervention to improve cognitive parameters in children: The Active-Start study. *Scandinavian Journal of Medicine & Science in Sports, 30*(1), 108-116. https://doi.org/10.1111/sms.13537

Ghahramani, M. H., Sohrabi, M., Kakhki, A. S., & Besharat, M. A. (2016). The Effects of Physical Activity on Impulse Control, Attention, Decision-Making and Motor Functions in Students with High and Low Impulsivity. *Biosciences Biotechnology Research Asia, 13*(3), 1689-1696. http://dx.doi.org/10.13005/bbra/2318

Goulardins, J. B., Marques, J. C. B., Casella, E. B., Nascimento, R. O., & Oliveira, J. A. (2013). Motor profile of children with attention deficit hyperactivity disorder, combined type. *Research in Developmental Disabilities, 34*(1), 40-45. https://doi.org/10.1016/j.ridd.2012.07.014

Haywood, K. M., & Getchell N. (2009). *Life Span Motor Development* (5th ed.). Human Kinetics.

Hraste, M., De Giorgio, A., Jelaska, P. M., Padulo, J., & Granić, I. (2018) When mathematics meets physical activity in the school-aged child: The effect of an integrated motor and cognitive approach to learning geometry. *PloS One, 13*(8), e0196024. https://doi.org/10.1371/journal.pone.0196024

Huang, C., Tu, H., Hsueh, M., Chiu, Y., Huang, M., & Chou, C. (2020). Effects of Acute Aerobic Exercise on Executive Function in Children with and without Learning Disability: A Randomized Controlled Trial. *Adapted Physical Activity Quarterly, 37*(4), 404-422. https://doi.org/10.1123/apaq.2019-0108

Kamijo, K., Pontifex, M. B., O'Leary, K. C., Scudder, M. R., Wu, C. T., Castelli, D. M., & Hillman, C. H. (2011). The effects of an afterschool physical activity program on working memory in preadolescent children. *Developmental Science, 14*(5), 1046–1058. https://doi.org/10.1111/j.1467-7687.2011.01054.x

Kashfi, T. E., Sohrabi, M., Saberi Kakhki, A., Mashhadi, A., & Jabbari Nooghabi, M. (2019). Effects of a motor intervention program on motor skills and executive functions in children with learning difficulties. *Perceptual and Motor Skills, 126*(3), 477-498. https://doi.org/10.1177/0031512519836811

Lopes, L., Santos, R., Pereira, B., & Lopes, V. P. (2013). Associations between gross motor coordination and academic achievement in elementary school children. *Human Movement Science, 32*(1), 9-20. https://doi.org/10.1016/j.humov.2012.05.005

Medical Subject Headings (1999, January 1). *National Library of Medicine – "Child"*. https://www.ncbi.nlm.nih.gov/mesh/68002648

Methley, A. M., Campbell, S., Chew-Graham, C., McNally, R., & Cheraghi-Sohi, S. (2014). PICO, PICOS and SPIDER: a comparison study of specificity and sensitivity in three search tools for qualitative systematic reviews. *BMC Health Services Research, 14*(1), 1-10. https://doi.org/10.1186/s12913-014-0579-0

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Group (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Medicine, 6*(7), e1000097. https://doi.org/10.1371/journal.pmed.1000097

Newell, K. M. (2020). What are Fundamental Motor Skills and What is Fundamental About Them?. *Journal of Motor Learning and Development, 8*(2), 280-314. https://doi.org/10.1123/jmld.2020-0013

Oñate Navarrete, C. J., Aranela Castro, S. C., Navarrete Cerda, C. J., & Sepúlveda Urra, C. A. (2021). Association of the focus on motor competence and motor skills, with the maintenance of adherence to physical activity in adolescents. A scoping reviews. *Retos, 42*, 735–743. https://doi.org/10.47197/retos.v42i0.86663

Ouzzani, M., Hammady, H., Fedorowicz, Z., & Elmagarmid, A. (2016). Rayyan - a web and mobile app for systematic reviews. *Systematic Reviews, 5*, Article 210. https://doi.org/10.1186/s13643-016-0384-4

Pieters, S., Desoete, A., Van Waelvelde, H., Vanderswalmen, R., & Roeyers, H. (2012). Mathematical problems in children with developmental coordination disorder. *Research in Developmental Disabilities, 33*(4), 1128-1135. https://doi.org/10.1016/j.ridd.2012.02.007

Poeta, L. S., & Rosa Neto, F. (2007). Evaluación motora en escolares con indicadores del trastorno por déficit de atención/hiperactividad (Motor assessment in school-aged children with indicators of the attention deficit/hyperactivity disorder). *Revista de Neurología, 44*(3), 146-149. https://doi.org/10.33588/rn.4403.2005663

Priyadi, A. T., Wati, I. D. P., Amir, A., Siringo-ringo, T. G., Yuliana, Y. G. S., Khory, F. D., Sasataman B, P., Ghasya, D. A. V., Dafun JR, P. B. & Haetemi, M. (2024). How are motor skills and writing readiness in children?: A literature review. *Retos, 61*, 141-147. http://doi.org/10.47197/retos.v61.109558

Rosa Neto, F., Santos, A. P. M., Xavier, R. F. C., & Amaro, K. N. (2010). Motor Importance of motor assessment in school children: analysis of the reliability of the motor development scale. *Revista Brasileira de Cineantropometria e Desempenho Humano, 12*(6), 422-427. https://doi.org/10.5007/1980-0037.2010v12n6p422

Sartori, R. F., Nobre, G. C., Fonseca, R. P., & Valentini, N. C. (2021). Do executive functions and gross motor skills predict writing and mathematical performance in children with developmental coordination disorder? *Applied Neuropsychology: Child, 11*(4), 825–839. https://doi.org/10.1080/21622965.2021.1987236

Silveira, C. R. A., Menuchi, M. R. T. P., Simões, C. S. A., Caetano, M. J. D., & Gobbi, L. T. B. (2006). Construction validity in equilibrium tests: chronological order in tasks presentation. *Revista Brasileira de Cineantropometria e Desempenho Humano, 8*(3), 66-72.

Veintimilla, A. M. U., Cheme, R. K. G., Muñoz, H. Z. ., Chavarría, M. T., & Vélez, W. A. Z. (2024). Psychopedagogy in the application of recreational games with students with specific learning difficulties. *Retos, 55*, 992–998. https://doi.org/10.47197/retos.v55.104617

Vetter, M., O'Connor, H., O'Dwyer, N., & Orr, R. (2018). Learning "Math on the Move": Effectiveness of a Combined Numeracy and Physical Activity Program for Primary School Children. *Journal of Physical Activity and Health, 15*(7), 492-498. https://doi.org/10.1123/jpah.2017-0234

Vieira, M. E., Ribeiro, F. V., & Formiga, C. K. (2009). Principais instrumentos de avaliação do desenvolvimento da criança de zero a dois anos de idade. *Movimenta, 2*(1), 23-31.

Visser, L., Röschinger, J., Barck, K., Büttner, G., & Hasselhorn, M. (2020). Learning Difficulties in Children with Symptoms of DCD And/or ADHD: Analyses from a Categorical and a Continuous Approach. *International Journal of Disability, Development and Education, 69*(5), 1505–1521. https://doi.org/10.1080/1034912X.2020.1786023

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*(6), 2773-2779. https://doi.org/10.1016/j.ridd.2011.05.032

Authors' and translators' details:

Ricardo de Almeida Pimenta	ricardo.pimenta@ufsc.br	Author/Translator
Raphael Teixeira de Almeida Ramos	almeida01@ufrrj.br	Author
Lisiane Schilling Poeta	lisiane.poeta@ufsc.br	Author
Fabiane Frota da Rocha Morgado	fabianefrota@ufrrj.br	Author