ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research

Vol. 10, Issue, 04, pp. 35298-35302, April, 2020

https://doi.org/10.37118/ijdr.18608.04.2020

RESEARCH ARTICLE

OPEN ACCESS

CORRELATION BETWEEN EXECUTIVE FUNCTIONS AND MOTOR DEVELOPMENT

***Rodrigo Carlos Toscano Ferreira, Ronê Paiano, Armando dos Santos Afonso Junior, Silvana Maria Blascovi de Assis and Luiz Renato Rodrigues Carreiro**

Postgraduate Program in Developmental Disorders, Mackenzie Presbyterian University. São Paulo-SP - Brazil

ARTICLE INFO

Article History:

Received 18th January, 2020

Received in revised form

24th February, 2020

Accepted 01st March, 2020

Published online 30th April, 2020

Key Words:

Executive Function, Motor skills, Development, Child.

****Corresponding author:***

Rodrigo Carlos Toscano Ferreira

ABSTRACT

Executive functions (EF) refer to a series of cognitive processes that allow individual to control and regulate his behavior before the demands and environmental requirements. Literature data indicate a possible association between motor development (MD) and EF; therefore, this study aimed to investigate the relationship between MD and EF in children aged 7-9. Seventy-nine children enrolled between the 2nd to 4th grades of Elementary School in a private school in the City of São Paulo participated in this study. Movement Assessment Battery for Children – Second Edition (MABC-2) was used for the evaluation of MD and Trail Making Test; Attention by Cancelling Test (ACT) and Inventory of difficulties in Executive Function regulation and aversion to delay (IFERA-I) were used for EF. Pearson correlation analysis was carried out with the obtained data and the results showed a positive correlation between motor skills and EF. The association between MABC-2 and ACT obtained a significant correlation with $p<0,007$, and the MABC-2 total performance with TMT also showed significant correlation, being ($p<0.011$) in part A, ($p<0.003$) in part B and ($p<0.016$) in part B - A. However, further studies should be conducted to conclude the real impact of motor development on cognitive skills.

Citation: ***Rodrigo Carlos Toscano Ferreira, Ronê Paiano, Armando dos Santos Afonso Junior, Silvana Maria Blascovi de Assisand Luiz Renato Rodrigues Carreiro.*** **2020.** "Correlation between executive functions and motor development*", International Journal of Development Research*, 10, (04), 35298-35302.

INTRODUCTION

Executive functions (EF), also known as executive control or cognitive control, are a set of cognitive processes that allow individual to control and regulate his behavior before the demands and environmental requirements (Diamond, 2013). According to the model proposed by her, the main components of the EFs are: (1) inhibitory control; (2) working memory and (3) cognitive flexibility. Inhibitory control is the ability to think before to act, not to give answers considered impulsive, to resist distractions and to remain in focus. Working memory is the ability to bear in mind the information and mentally work with them, exploring ideas/facts relations and updating thoughts and planning. Cognitive flexibility is the ability to adapt to changed requirements or priorities, to take advantages and unexpected opportunities, or to overcome sudden problems (Diamond, 2013).EFs contribute to the implementation of many activities of everyday life. They are fundamental to the individual learning and functioning in an appropriate manner to the rules and the demands of different contexts.

When these abilities are impaired or do not develop properly, many problems can occur. The individual can become inattentive, impulsive, have difficulty in expressing his ideas and plans; to finish an activity or to be able to engage in complex behaviors; he may experience further difficulty in regulating his emotions, not managing to delay gratification, showing irritability, among others (Dias *et al*., 2013). From an academic point of view, researches indicate a direct relationship between EF and school learning. In a review of EF and metacognition, Marulis *et al*. (2019) identify the EF as an essential processin a variety of contexts, able to impact on emotional, social and cognitive development, predicting positive results in learning and academic performance. Lima *et al*. (2009) related EF and school performance of 36 children without learning disabilities, from the Elementary School. The results showed that the performance of students followed the development of attention and EF. León *et al*. (2013) investigated the relationship between EF and academic performance of 40 children between 6-9 years old of a public school in São Paulo. They used the Inventory of difficulties in Executive Function regulation and aversion to delay (IFERA-I) and the bimonthly notes of the school year as evaluation instruments. It was found that children assessed by their parents and teachers as having better executive skills also had better school performance, even in the early stages of elementary school. In order to expand the understanding of learning, few studies have investigated the association between cognitive skills and motor development (MD). Palace *et al*. (2016) emphasized the relationship between cognitive and motor development in children, noting that well-developed motor skills are fundamentals to satisfactory academic performance in reading, writing and arithmetic. To study the correlation of motor coordination with the EF, Fernandes *et al*. (2016) evaluated 45 children, from 8 to 14 years old, through various instruments. The results showed a significant correlation between them; that is, children who performed better in coordination test, have also presented better scores in EF tests. Rigoli *et al*. (2012) also showed a positive correlation in their results, pointing, still, at relations of motor coordination with specific areas of EF, such as the association between manual dexterity and working memory.

Finally, they still observed the importance of identifying motor difficulties in those with problems in EF, a first step to propose an appropriate intervention. As justification and scientific relevance to this work, it is highlighted the few national academic productions that deal with this issue in children without learning complaints. From a social and applied point of view, it emphasizes identifying opportunities to minimize the learning difficulties encountered by children in the school environment, deepening the understanding of factors that influence the cognitive and motor skills. Therefore, this article aims to describe and analyze the correlations between motor development and executive functions of children aged 7-9, with no complaints of learning disability and without neurodevelopmental disorder indicators.

MATERIALS AND METHODS

Data were collected in a private school in São Paulo. The participants were students of high socioeconomic level and chosen for convenience. The study included 79 children, 41 boys and 38 girls, 7-9 years old, enrolled from the2ndto the4th year of Elementary School 1. As exclusion criteria, the reports of neurodevelopmental disorders or deficiencies in school records of students were checked. Ethical procedures were submitted and approved by the Ethics Committee in research involving humans form Mackenzie University under the CEP process nº 3. 094.831, December 2018, and CAAE No. 01575018.5.0000.0084.

Four instruments were used in this study: Movement Assessment Battery for Children Scale– Second Edition (MABC-2). It is a standard gold instrument for the diagnosis of DCD (Developmental Coordination Disorder) used for assessing motor skills. It was developed and produced in England by Henderson and Sugden (1992) and had the second edition published in 2007 (Henderson, Sugden and Barnett). The MABC- 2 is divided into 03 bands according to the age group: Section 01, 03-06 years old; section 02, 07-10 years old and section 03, 11-16 years old. Each section contains 08 tasks divided into manual dexterity, ball skills and static and dynamic balance. Depending on the task, the performance is measured by time and/or number of hits and errors and their values are converted to a scale in standardized scores.

The Brazilian version of MABC-2, band 2, had been translated and had cross-cultural adaptation by Catelli *et al*. (2018). Only the part of the instrument quantitative evaluation was used in this study because of the option to use scores generated by MABC-2 for performing the correlation tests. The use of this instrument occurred due to prior permission of the publisher, through a signed contract.

The Inventory of difficulties in Executive Function regulation and aversion to delay(IFERA-I): It was developed by Trevisan and Seabra (2014) to assess the parents and teachers report on the use of EF skills in daily tasks, at home and at school. It aims to assess executive functioning through a functional measure and should be answered by parents and teachers. The IFERA-I consists of 28 items divided into five subscales: Working Memory - WM (5 items); Inhibitory Control - lC (6 items); Flexibility - FL (5 items); Delay Aversion - DA (5 items) and Regulation - RG (7 items). Each of the 28 items is rated on a Likert scale of 5 items, such as: "never," "rarely," "sometimes," "often" and "always", which are scored from 1 to 5, respectively.

The Trail Making Test It was developed by Montiel & Seabra (2012) and evaluates executive functions and consists of items that should be connected according to a predetermined sequence. The test has two parts, part A consists of a first sheet in which are shown 12-letter, from "A" to "L" (before spelling reform) and then another sheet with 12 numbers from "1" to "12". This partrequires the connection of the items in alphabetical and numerical order, respectively. Part B presents letters and numbers randomly arranged with 24 items (12 letters and 12 numbers) to be connected alternately in alphabetical and numerical order (Dias; Tortella, 2012).

Attention by Cancellation Test (ACT): It was also developed by Montiel & Seabra (2012), based on the classic paradigm of stimuli cancellation and consists of three parts. Each part has a training sheet and a test sheet, the second one presenting 300 stimuli (geometric shapes) and evaluating selective attention (Parts 1 and 2) and alternating and selective attention (Part 3). The individual must point out all the stimuli that are equal to the predetermined target stimulus (Godoy, 2012). For this study, we chose the collective application. In part 1, there is only one target stimulus and the child should cancel all identical stimuli to the target (Godoy, 2012). In part 2, the complexity of the task is higher as the target stimulus comprises a pair of double figures, which must be arranged side by side on the same line and order. (Godoy, 2012).

In part 3, the target stimulus is presented at the beginning of each line, requiring the alternation of attention among each target to execute the task. (Godoy, 2012). As for the test application sequence, neuropsychological tests in groups were initially applied; then, the assessment was done individually by the researcher using the MABC-2, with careful explanation and appropriate intervals. Pearson correlation analysis was used to establish the desired results and to verify possible significant relevance. For this work, a significance level of 0.05 (5%) was defined. Therefore, all intervals of this research were built with 95% of statistical confidence. However, the values $0.05<p<0.1$ for being close to the limit of acceptance, have been found to tend to be significant (up to 5 percentage points above the alpha value adopted). That is why they were also described in the results.

RESULTS AND DISCUSSION

In the correlation results between MABC-2 and ACT, significant interactions were found in manual dexterity and in the total score. However, there was no significant correlation including the ability to play/to grab and balance. The final scores of correlation between the two instruments, total ACT and MABC-2, a significant correlation ($p<0.007$) was obtained (Table 1).

Sá *et al*. (2018) carried out a study to analyze the influence of psychomotor intervention on motor development and levels of attention in children with motor delay, and so, as in the present study, they used the MABC-2 for motor development and the ACT for levels of care. The researchers applied an instrument for the evaluation of attention in 28 children aged 7, 8 and 9 years old, before and after the psychomotor intervention (lasting 20 sessions); thus, they could assess the students' evolution.

Table 1. Correlation between MABC -2 and ACT

SCALES		*r*	*p*	*n*
MABC-2	ACT	*Pearson*		
	ACT 1	0.264 *	0.019	79
Manual	ACT 2	0.296 **	0.009	77
Dexterity	ACT 3	0.266 *	0.019	78
	Total	0.401 **	0.001	79
	ACT 1	-0.018	0.875	79
To Play/	ACT 2	0.135	0.24	77
To Grab	ACT 3	-0.076	0.511	78
	Total	0.106	0.352	79
	ACT 1	0.153	0.178	79
Balance	ACT 2	0.179	0.119	77
	ACT3	-0.164	0.152	78
	Total	0.087	0.444	79
	ACT 1	0.2	0.077 °	79
Total	ACT 2	0.317 **	0.005	77
	ACT 3	0,065	0.571	78
	Total	0.303	0.007 **	79

Key * = p<0.05; ** = p<0.01 and°= 0.05 <p<0.1

Table 2. Correlation between MABC-2 and Trail Making Test

scales		*r*	*p*	*n*
MABC-2	Trail	*Pearson*		
	Trails A	0.191 °	0.094	78
Manual dexterity	Trails B	0.270 *	0.017	78
	Trails B -A	0.221 °	0.054	77
	Trails A	0.051	0.66	78
To Play/To Grab	Trails B	0.155	0.174	78
	Trails B -A	0.167	0.146	77
	Trails A	0.332 **	0.003	78
Balance	Trails B	0.334 **	0.003	78
	Trails B -A	0.251 *	0.028	77
	Trails A	0.268 *	0.011	78
Total	Trails B	0.328 **	0.003	78
	Trails B -A	0.275 *	0.016	77

Key * = p<0.05; ** = p<= 0.01 and °=0.05 <p<0.1

Table 3. Correlation between MABC-2 and IFERA-I answered by teachers

scales		*r*	*p*	*n*
2-MABC	IFERA-I	*Pearson*		
	Inhibitory Control	0.035	0.762	79
	Working Memory	-0.026 *	0.021	79
Dexterity	Cognitive Flexibility	-0.055	0.631	79
Manual	Delay Aversion	0.02	0.864	79
	Self -Regulation	-0.068	0.551	79
	Total	-0.082	0.773	79
	Inhibitory Control	0.162	0.153	79
	Working Memory	-0.052	0.647	79
To Play/To Grab	Cognitive Flexibility	0.045	0.693	79
Take	Delay Aversion	0.13	0.254	79
	Self- Regulation	0.042	0.714	79
	Total	0.071	0.531	79
	Inhibitory Control	-0.071	0.535	79
	Working Memory	-0,111	0.331	79
Balan ce	Cognitive Flexibility	0.015	0.897	79
	Delay Aversion	-0.041	0.717	79
	Self -Regulation	-0.053	0.664	79
	Total	-0.066	0.566	79
	Inhibitory Control	0.013	0.912	79
	Working Memory	-0.232 *	0.039	79
Total	Cognitive Flexibility	-0.051	0.657	79
	Delay Aversion	0.013	0.912	79
	Self -Regulation	-0.082	0.475	79
	Total	-0.084	0.461	79

The results showed significant improvement of the ATC part 1 and a significant trend in total ACT, possibly supported by the score of part 1 itself. The results presented in this paper corroborate the results of Sá and co-workers (2018), in which a significate correlation ($p<0.007$) between the total score of MABC-2 and ACT was found. That is, the better the motor development, the higher the score in the attention level. Importantly, when assessing the motor skills separately, statistically significant evidence was observed at a level of 5% in all ACT tasks only with manual dexterity. The skills to play/tograb and balance showed no significant correlations in any part of the instrument. Therefore, the possible importance of fine motor coordination in attention levels of children may be taken into consideration. Regarding the Trail Making Test, there is a significant correlation in all parts (A, B and B - A) related to manual dexterity skills, balance and total score, noting that only in the item to play/to grab there was no significant correlation. The MABC-2 total performance showed correlated significantly in all parts of the Trails, being ($p<0.011$) in part A, ($p<0.003$) in part B and ($p<0.016$) in part B - A (Table 2). By analyzing, the Trail Making Test with the specific motor skills evaluated by MABC-2, manual dexterity and balance are relevant, just to play/to grab showed no significance.

So, according to the results, it is evident a possible relationship of motor development with the EF, specifically cognitive flexibility, the most relevant construct in the Trail test. Veldman *et al*. (2019) evaluated the global motor coordination in relation to the cognitive development of 335 Australian preschools, and the results showed a significant correlation in the assessed constructs, corroborating with the findings of this study. On the other hand, Kelley (2019) examined a short motor intervention program (10 sessions) and its impact on EF scores in preschools. EF pre-tests and post-tests were carried out to identify possible benefits of the intervention, but the results showed no significant differences in test scores after the intervention. The author cites as study limitation the few sessions of motor intervention. More studies in this area will be important for a full understanding of the subject. Table 3 describes the correlation between MABC-2 and IFERA-I, answered by the classroom teacher. It is possible to observe a significant correlation only between the constructs of the working memory with the manual dexterity ($p<0.021$) and the total amount ($p<0.039$).

The IFERA-I, answered by teachers, did not show a significant correlation with the majority ofMABC-2motor skills. There were not found any studies in the literature that specifically discuss the association of IFERA-I behavioral instrument and motor development. These results were not expected given the study hypothesis that better motor development indices were associated with better scores of executive functions and, consequently, lower behavioral complaints. Some researchers, especially involving children with Autism Spectrum Disorder, have also studied the correlation between EF and MD in children with atypical development. Carvalho *et al*. (2020) assessed motor performance, intelligence and EF of 18 children and adolescents diagnosed with ASD, between 9 and 13 years old. Some of the instruments used were the same as this article: MABC-2 for the motor skills and Trail Making Test and ACT to the EF. These results were corroborated by the findings of this study, that is, the higher the commitment of EF, the more significant the impairment of motor skills.

Final Considerations

Based on these data, it is possible to reach essential considerations. The hypothesis that there is a correlation between EF and MD was reaffirmed in the studied group. That is, participants who had better scores in EF tests also obtained better MD rates. Interestingly, there was significant statistical evidence on the level of 1% as the correlation results with ACT with MABC-2 total, showing that the better the MD scores, the better the attentional levels of students. Concerning cognitive flexibility and working memory, predominant constructs of EF in the Trails test, there was also a significant statistical correlation; again, students with better scores in this test were the same that obtained better results in MD. It is important to highlight that when we analyzed the specific motor skills, manual dexterity was the skill with the highest correlation with the EF. Some literature data corroborate with the found results. Freitas (2011) studied the relationship between executive function and fine motor skills in children with attention deficit hyperactivity disorder (ADHD), the described results point out that symptoms of inattention are related to problems with fine motor skills. Ultimately, it is considered that the survey had a small sample, consisting of participants in a private school of higher socioeconomic status, which differs from the reality of most Brazilian children. Thus, it is necessary to continue this study with more significant and representative samples. Another point to be highlighted is the need to analyze the child's development in a contextualized way, considering aspects of social and emotional development as well asa regular physical activity outside of school. Therefore, from the results presented, it can be considered that the motor skills should be treated with relevance in the education context. Further studies should be carried out in the area for a greater understanding and conclusions despite the specific motor skills and their possible impact on children's EF.

Acknowledgments: This study was Financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil - (CAPES) - Finance Code 001.

REFERENCES

Carvalho, ACR; Farms, RHR; Blascovi-Assis, SM; Alessandra Gotuzzo. 2020. "Engine performance, intelligence, and executive functions in children with ASD." International Journal of Development Research, 10, (02), 34053-34060.

Days, NM; Seabra AG. 2013. Executive Functions: development and intervention. Themes of development, v. 19, no. 107, p. 206-212.

Diamond, A. 2013. Executive Functions. Annual Review of Psychology, Vol. 64, p. 135- 168.

Fernandes, VR; Ribeiro, MLS; Melo, T; Pinheiro, MTP; Guimaraes, TT; Araujo, NB; Deslandes, AC. 2016. Motor Coordination Correlates with Academic Achievement and Cognitive Function in Children. Frontiers in Psychology, Vol. 7, p. 1-8.

Freitas, GMPM.2011. Relationship between executive function and fine motor skills in children with attention deficit disorder / hyperactivity disorder. Dissertation (Masters in Neuroscience) Graduate Program in Neuroscience at the Institute of Biological Sciences, Federal University of Minas Gerais, Belo Horizonte, Brazil.

Godoy, S. 2012. Evidence of validity of the cancellation attention test. cognitive neuropsychological assessment: attention and executive functions, São Paulo, Memnon.

Henderson, SE; Sugden, DA; BARNETT, AL. 2007. Movement Assessment Battery for Children-2.2nd edition. London: The Psychological Corporation.

Kelley, M. 2019. Executive function and motor skills in preschool children. Distinctions Papers, 73.

Leon, CBR., Rodrigues, DC., Seabra AG., Dias, NM. 2013. Executive Functions and school performance in children 6-9 years old. Psychology Magazine, vol. 30, no. 92, p. 113-120.

Lima, RF., Travaini, PP., Ciasca, SM. 2009. Sample performance of elementary school students on tests of attention and executive functions. Psychology Magazine, vol. 26 n. 80, p. 188-99.

Marulis, LM., Baker, TS., Whitebread, D. 2019. Integrating metacognition and executive functions to Enhance young children's perception of learning and in Their agency. Early Childhood Research Quarterly.

Montiel JM Seabra AG. 2012. Pattern of tracks A and B. In: SEABRA AG; DAYS, NM (Orgs) Evaluation neuropsychological cognitive: attention and executive functions. São Paulo, Memnon, v.1.

Montiel, JM., Seabra, AG. 2012. Attention Test for cancellation. In: SEABRA AG; DAYS, NM (Orgs) Evaluation neuropsychological cognitive: attention and executive functions. São Paulo, Memnon,v.1.

Palace, SG; Oliveira, JA; Arneiro RFM. 2016. Assessment of skills and school performance engine in children diagnosed with attention deficit hyperactivity disorder. Motive: Journal of Physical Education. v. 22, n.4.

Rigoli, D., Piek, J., Kane, R., Oosterlaan, J. 2012. An examination of the relationship between motor coordination and executive functions in adolescents. Developmental Medicine & Child Neurology, Vol. 54, no. 11, p. 1025-1031.

SA, MV., Lara, S., Graup, S; Balk, RS., Sasso, RR. 2018. Analysis of motor development and attention of children subjected to psychomotor intervention program. ConsSaude v. 17, no. 2, p. 187-195.

Trevisan, BT., Seabra AG. 2014. Inventory difficulties in Executive Functions, Regulation and aversion postponement - children's version (IFERA-I).

Veldman, SLC., Santos, R., Jones, RA., SA, ES., Okely, AD. 2019. Associations between gross motor skills and cognitive development in toddlers. Early Human Development. v. 132, p. 39-44.

****