Original Article

Association between cognitive function and gross motor development in children with neurodevelopmental disorders

Associação entre função cognitiva e desenvolvimento motor grosso de crianças com transtornos do neurodesenvolvimento

Isadora Martins Álvares[1]
Daniella Oliveira Lara[2]
Náguia Letícia Medeiros[3]
Hércules Ribeiro Leite[4]
Ana Cristina Resende Camargos[5]

[1-4]Universidade Federal de Minas Gerais (Belo Horizonte). Minas Gerais, Brasil.
isadoramartinsalvares@gmail.com, lara.daniellaoliveira@gmail.com, naguiamedeiros@ufmg.br, hercules@ufmg.br
[5]Autora para correspondência. Universidade Federal de Minas Gerais (Belo Horizonte). Minas Gerais, Brasil. anacrcamargos@ufmg.br

ABSTRACT | INTRODUCTION: Children with neurodevelopmental disorders have a variety of conditions that, in general, cause cognitive impairments, as well as, limitations to perform gross and fine motor activities resulting from deficits in balance and motor coordination. **OBJECTIVE:** This study verified whether the cognitive function is associated and could predict outcomes of gross motor development in children with neurodevelopmental disorders between 5 and 10 years of age. **METHODS:** We carried out an exploratory cross-sectional study with 25 children with neurodevelopmental disorders, between 5-10 years of age, able to walk independently. The children's version of the Mini-Mental State Examination and the Gross Motor Development Test - second edition-evaluated the cognitive function and gross motor abilities. A simple linear regression analysis was performed, and the effect size was calculated. **RESULTS:** Fifteen (60%) were male, with a mean age of 7.81 (± 1.90), seven with intellectual disability, eight with autism spectrum disorder, five with attention deficit hyperactivity disorder, two with communication disorders, and three with specific learning disorders. The Mini-Exam State Examination score was significantly associated and explained the variability of locomotion skills (R^2=0.25; p=0.006), object control skills (R^2= 0.29; p=0.003), and the gross motor quotient (R^2=0.40; p=0.0001). **CONCLUSION:** We concluded that cognitive function is associated with gross motor skills and could explain their development in children with neurodevelopmental disorders between 5 and 10 years of age. These results might contribute to a better understanding of the influence of cognitive function on the development of gross motor skills in this population.

KEYWORDS: Cognitive function. Motor development. Neurodevelopmental disorders.

RESUMO | INTRODUÇÃO: Crianças com transtornos do neurodesenvolvimento apresentam uma variedade de condições que, em geral, possuem comprometimento da função cognitiva, bem como limitações para realizar atividades motoras grossas e finas decorrentes do déficit de equilíbrio e da coordenação motora. **OBJETIVO:** O presente estudo teve por objetivo verificar se a função cognitiva está associada e pode predizer desfechos do desenvolvimento motor grosso em crianças com transtornos do neurodesenvolvimento entre 5 e 10 anos de idade. **MATERIAIS E MÉTODOS:** Foi realizado um estudo transversal exploratório com 24 crianças com transtornos do neurodesenvolvimento, entre 5-10 anos de idade, capazes de deambular independente. Para avaliar a função cognitiva e as habilidades motoras grossas das crianças foram utilizados o Mini-Exame do Estado Mental e o Teste de Desenvolvimento Motor Grosso – segunda edição, respectivamente. Análise de regressão linear simples foi realizada e o tamanho do efeito calculado. **RESULTADOS:** Quinze (60%) eram meninos, com idade média de 7,81 (± 1,90), sete com deficiência intelectual, oito com transtorno do espectro autista, cinco com transtorno do déficit de atenção e hiperatividade, dois com transtornos de comunicação e três com transtornos específicos de aprendizagem. A pontuação do Mini-Exame do Estado Mental foi significativamente associada e capaz de explicar a variabilidade das habilidades de locomoção (R^2=0,25; p=0,006), das habilidades de controle de objetos (R^2=0,29; p=0,003) e do quociente motor grosso (R^2=0,40; p=0,0001). **CONCLUSÃO:** A função cognitiva está associada e pode explicar o desenvolvimento motor grosso de crianças com transtornos do neurodesenvolvimento entre 5 e 10 anos de idade. Esses resultados podem contribuir para um melhor entendimento da influência da função cognitiva no desenvolvimento das habilidades motoras grossas dessa população.

PALAVRAS-CHAVE: Função cognitiva. Desenvolvimento motor. Transtornos do neurodesenvolvimento.

How to cite this article: Álvares IM, Lara DO, Medeiros NL, Leite HR, Camargos ACR. Association between cognitive function and gross motor development in children with neurodevelopmental disorders. J Physiother Res. 2021;11(2):393-400. http://dx.doi.org/10.17267/2238-2704rpf.v11i2.3779

Submitted 04/20/2021, Accepted 05/11/2021, Published 05/26/2021
J. Physiother. Res., Salvador, 2021 May;11(2):393-400
http://dx.doi.org/10.17267/2238-2704rpf.v11i2.3779 | ISSN: 2238-2704
Designated editors: Kátia Sá e Cristiane Dias

Introduction

Neurodevelopmental Disorders (NDD) is a group of health conditions that include: intellectual disability (ID), autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD), specific learning disorders, communication disorders, motor disorders, and other specified and unspecified neurodevelopmental disorders. These disorders initiate during child development.[1]

Children with NDD have various conditions that generally cause cognitive and function impaired ranging from milder to deeper forms.[2,3] Therefore, these deficits could be involved in controlling executive functions, limitations in learning, and/or global losses in intelligence and social skills.[1] Children with ID have impairments in their intellectual function, related to reasoning, problem-solving, planning, abstract thinking, judgment, academic learning, and learning from experience, as well as an adaptive function, which limit their performance in activities of daily living, communication, participation and independent living.[1] Children with ASD tend to experience impairments in regulating attentional focus and impairment in executive function skills[4], leading to difficulties when changing or initiating new tasks.[5] Children with ADHD have a continuous pattern of inattention, disorganization, and/or hyperactivity-impulsivity, with difficulty maintaining a focus on an activity[1], which generally leads to learning difficulties and executive function deficits, with impaired cognitive function.[6] Children with specific learning disorders have difficulty perceiving or processing verbal or non-verbal information with competence and accuracy, resulting in permanent difficulties in learning academic skills.[1] On the other hand, children with communication disorders have difficulty understanding, expressing, and/or communicating verbally and/or non-verbally, with restrictions on academic success due to not having effective communication.[1]

In addition to impaired cognitive function, these children often have limited capacity to perform gross and fine motor activities resulting from balance disorders and motor coordination.[7,8] The literature points out that children with ID have motor limitations, mainly in static and dynamic balance activities, activities with ball and locomotion.[9,10] In children with ASD, there is a deficit in balance[11], motor coordination, and difficulty in preparing, planning, timing and organizing movements.[12] Children with ADHD may have impaired static and dynamic balance and fine and gross motor coordination.[7,13] Children with specific learning disorders, on the other hand, usually have a deficit in motor coordination, with reduced autonomy in daily living tasks.[8]

It is important to verify if they are related, considering that children with different conditions that comprise the NDD commonly present impairment on cognitive function and gross motor limitations. Thus, this study aimed to verify whether the cognitive function is associated and explain the variability in gross motor skills in children with NDD between 5 and 10. The findings of this study may contribute to a better understanding by health professionals of how cognitive function can interfere with the acquisition of gross motor skills.

Materials and methods

Study design

This is an exploratory cross-sectional study aimed to investigate the association between cognitive function and gross motor development of children with NDD. The study is a secondary analysis of data from a major study entitled "Motor skills and functional performance of children with neurodevelopmental disorders," approved by the Ethics Committee of the Federal University of Minas Gerais (CAAE 86122318.6.0000.5149).

Participants

All the children with NDD that attended the rehabilitation clinics in the city of Belo Horizonte were eligible to participate in the study as long as they fulfilled the inclusion and exclusion criteria. There were included children with NDD aged between 5-10 years of age, able to walk independently, and whose parents/or guardians signed the consent form. Children whose parents refused to participate in the study or were absent on the days of data collection were excluded.

The sample size calculation was performed according to the study of Ribeiro[14], which considered R^2=0.27 and effect size (d)=0.37, Power=0.80, and only one predictor (cognitive function). Thus, 24 children with NDD were needed to compose the sample size.

Instruments

The Mini-Mental State Examination (MMSE) adapted for children was used to assess the children's cognitive function. It is a simple and fast instrument in which it is possible to perform the screening for cognitive impairment. This instrument was initially created to assess adults but was adapted and validated for children aged 3 to 14 years of age by Jain and Passi.[15] It evaluates responses about orientation, memory, and attention, in addition to verbal and written commands, considering as a cutoff point the score of two standard deviations below the average, according to the age group.[15] The numerical score provided by the instrument was used to assess the association between cognitive function and gross motor development. According to the cutoff points of each age group, children were classified as normal or with cognitive delay to characterize the sample.

The Gross Motor Development Test - second edition was used (Test of Gross Motor Development - second edition - TGMD-2)[16] To assess gross motor development. The TGMD-2 is a test referenced by standard and criteria, with individual rules for the development of boys and girls between three and ten years old, which evaluates how children coordinate the trunk and limbs while performing a motor skill in order to verify the presence or absence of different components of skills instead of evaluating only the end product performance.[16] The test was translated and proved to be reliable for Brazilian children in the study by Valentini et al.[17] This test allows an independent assessment of each subtest (locomotion and object control) and also in the subtest of object control, with differentiation by gender.

The TGMD-2 assesses 12 gross motor skills: locomotion skills (run, gallop, hop, leap, horizontal jump, and slide), and six are object control skills (striking a stationary ball, stationary dribble, catch, kick, overhand throw, underhand roll). For each skill of the subtests, 3 to 5 specific motor criteria are observed, which are based on mature movement patterns. Each item is scored in two attempts, in which you will receive a score of 1 if you can meet the criteria or 0 if you do not meet the criteria. The scores provide the overall score for each subtest (locomotion and control objects), which is converted into a standardized score. The standardized scores of each subtest are added and converted into the gross motor quotient, used to classify gross motor development as very superior, superior, above average, on average, below average, poor, and very poor.[16] We used the standardized score for each subtest and gross motor quotient to evaluate the association between cognitive function and gross motor development.

Procedures

Initially, contact was made with the rehabilitation clinics, and authorization was requested to perform data collection on-site by signing the consent letter. Children who fit the study profile were pre-selected, considering age and clinical diagnosis, and telephone contact was made with parents to schedule data collection. Parents who accepted their children's participation in the study signed an informed consent form. Then, they answered a questionnaire with information about the child's personal data and health condition. The collection started with the application of MMSE in children, followed by the application of TGMD-2, both performed individually. All children were tested in an appropriate, ventilated, and adequate space to conduct the tests. Four evaluators underwent training to apply the tests, and the reliability for their application was established (ICC (2.1) = 0.92).

Statistical analysis

The data were analyzed using the SPSS software, version 20.0. Descriptive statistics were used to characterize the sample. After checking the normal distribution, Pearson's correlation was used to check the association between cognitive function (MMSE score) and gross motor development (standardized locomotion score, standardized object control score, and gross motor quotient). Subsequently, simple linear regression analysis was performed between the predictor variable (MMSE score) and the outcome variables (standardized locomotion score, standardized object control score, and gross motor quotient). The effect size (d) was calculated using the G Power 3.1.9.2 software and the strength of the association was considered small (d = 0.02), medium (d = 0.15) or large (d = 0.35).

Results

We evaluated 25 children with NDD. Among these, seven (28%) with ID, eight (32%) with ASD, five (20%) with ADHD, two (8%) with communication disorders, and three (12%) with specific learning disorders. Ten (40%) children were female, and fifteen (60%) were male, with the average age of the participants being 7.81 (± 1.90). All children attended regular school. Two children (12%) underwent physiotherapeutic treatment, sixteen children (64%) underwent occupational therapy, the speech therapist was monitoring twenty children (80%), one (4%) was being monitored by a psychopedagogue, and seven (28%) were attending physical activity regularly. The children´s classification using cutoff point according to the MMSE and gross motor quotient, assessed by TGMD-2, were showed in Table 1.

Table 1. Classification of the participants according cutoff points of Mini-Mental State Examination and gross motor quotient

Classification	F (%)
Mini-Mental State Examination	
Within age range	8 (32%)
Cognitive delay	17 (68%)
Gross motor quotient	
Within the average	3 (12%)
Below average development	6 (24%)
Poor development	8 (32%)
Very poor development	8 (32%)

Legend: F = frequency.

Pearson's correlation was shown in Table 2.

Table 2. Pearson correlation between Mini Mental State Examination score and the Gross Motor Development Test score

	Mini-Mental State Examination	
Gross Motor Development Test score	r	p
Locomotion skills	0.53	0.006*
Ability to control objects	0.56	0.003*
Gross Motor quotient	0.66	0.0001*

Legend: r = Pearson´s coefficient.
*p value <0.05.

Table 3 showed the results for the analysis of simple linear regression. It was observed that the MMSE score was significantly associated and able to explain 25% of the variability of locomotion skills (p = 0.006; d = 0.79), 29% of the variability of object control skills (p = 0.003; d = 0.86) and 40% of the variability of the gross motor quotient (p = 0.0001; d = 0.97). Thus, the increase of 1 point in the MMSE led to an increase of 0.53 points in the subtest of locomotion skills, 0.53 points in the object control skills subtest, and 0.66 points in the gross motor quotient.

Table 3. Simple linear regression analysis between the Mini Mental State Examination score and the Gross Motor Development Test score

	Mini-Mental State Examination			
Variable	**B (IC95%)**	**β**	**R^2**	**SEE**
Locomotion skills	0,21 (0,07-0,36)	0,53	0,25	0,07*
Ability to control objects	0,20 (0,07-0,32)	0,53	0,29	0,06*
Gross Motor quotient	1,23 (0,62-1,84)	0,66	0,40	0,30*

Legend: B = regression coefficient; CI = confidence interval; β = standardized regression coefficient; R2 = adjusted determination coefficient; SEE = standard error of the estimate.
*p value <0.05.

Discussion

This study showed a strong association between cognitive function and motor development of children with NDD between 5 to 10 years old. The MMSE score explained the variability in the scores of locomotion skills, object control skills, and the motor quotient of the sample, with a large effect size.

The relationships between cognitive function and motor skills in childhood have been investigated for decades.[18] The literature has pointed out the association between cognitive and motor development in children with typical development, coactivating the neocerebellum and dorsolateral prefrontal cortex during motor and cognitive tasks.[19] Most of the studies found in the literature assess the influence of motor skills on cognitive function.[20] However, this study sought to investigate whether cognitive function, commonly impaired in children with NDD, could explain the variability of gross motor development of these children.

Studies have investigated the relationship between cognitive function and gross motor development in children with or without ID[21], with greater strength of the association in children with ID when compared to those without ID.[21] In general, the literature supports the premise that the relationship between cognitive and motor development is stronger in atypical populations.[22] One study compared the motor performance of children with ID classified as mild or borderline between seven and 12 years of age, and a higher proportion of motor limitations was identified in activities with the ball and in activities that require static and dynamic balance in children diagnosed with mild ID.[9] In the study by Westendorp et al.[10], the performance of motor skills was assessed in children with typical development, children with borderline ID, and children with mild ID in the same age group between 7 and 12 years old. In this study, children with borderline or mild ID had lower motor skills when compared to typical children, whereas children with borderline ID had greater locomotor skills when compared to those with mild ID.[10] However, no studies were found to investigate the relationship between cognitive function and gross motor skills in children with ASD, ADHD, specific learning disorders, and communication disorders. Our study identified that most of the sample (60%) comprised children with ID and ASD, and cognitive function partially explained the results of gross motor development.

Children with NDD may present impairment of cognitive function related to perception, attention, memory, language, and executive functions, with the impairment varying between different conditions with ID, ASD, ADHD, specific learning disorders, and communication disorders.[6,23] The impairment of cognitive function was identified in the present study in 68% of evaluated children, classified as below the cutoff point according to the MMSE adapted for children. This test consists of a cognitive impairment screening instrument[15] and has been used to assess children's cognitive function with learning difficulties due to the ease and speed of application.[24] It is sensitive to identifying moderate and severe cognitive changes in childhood for children above four years of age, but it is not very sensitive to identify mild degrees.[25] Thus, other diagnostic tests for assessing intellectual function have been indicated for more accurate assessment of cognitive function, such as, for example, the Wechsler Intelligence Scale for Children (Wechsler Intelligence Scale for Children- WISC).[26]

Children with NDD also commonly have a delay in developing gross motor skills, confirmed by the literature, which shows lower scores in tests of gross motor skills compared to children with different TND.[10,27] Most of the samples (88%) were classified below average gross motor development in the present study. The greatest difficulties are related to coordinated movements between the two sides of the body and the lower and upper extremities[10], with a longer reaction time to perform motor activities, limiting the development of both gross and fine motor skills.[13] The limitations to perform locomotion skills, such as running, jumping, galloping, and object control skills, such as kicking, receiving, and throwing a ball[5,28], can interfere with these children's participation in sports activities.[10] For the evaluation of gross motor development in children with NDD in Brazil, in addition to TGMD-2, the Motor Development Scale and the Movement Assessment Battery for Children, Second Edition - MABC-2) are used in research.[29]

It is important to consider that this study has some limitations. The first refers to the fact that we used a heterogeneous sample, including children with different conditions related to NDD. However, the variables of interest in the present study appear to be similar among this studied population.[2] Contextual factors, such as personal and environmental factors, can also interfere in the motor development of children with NDD. However, they were not evaluated in the present study. In addition, the study design was cross-sectional, not being able to verify the causal relationship.

However, it should be noted that this was the first study that found that cognitive function can explain the gross motor development of children with NDD, contributing to the knowledge of important points in the process of evaluating and planning the rehabilitation of children with NDD. These findings can assist clinicians who work with these conditions. Further studies are needed to verify the association of cognitive function and gross motor development in children with NDD.

Conclusion

Cognitive function is associated and may explain the gross motor development of children with NDD between 5 and 10 years of age. These results can contribute to a better understanding of the relationships between cognitive function and the development of gross motor skills in this population.

Authors 'contributions

Álvares IM participated in the conception, design, statistical analysis of the data, interpretation of the results, and writing of the scientific article. Lara DO participated in the conception, design, statistical analysis of the data, interpretation of results, and writing of the scientific article. Medeiros NL participated in the conception, design, and writing of the scientific article. Leite HR participated in the conception, design, statistical analysis of the data, interpretation of results, and writing of the scientific article. Camargos ACR participated in the conception, design, statistical analysis of the data, interpretation of the results, and writing of the scientific article.

Competing interests

No financial, legal, or political competing interests with third parties (government, commercial, private foundation, etc.) were disclosed for any aspect of the submitted work (including but not limited to grants, data monitoring board, study design, manuscript preparation, statistical analysis, etc.).

References

1. American Psychiatric Association. Manual Diagnóstico e Estatístico de Transtornos Mentais [Internet] 5ª. ed. Porto Alegre: Artmed; 2014. Available from: http://www.niip.com.br/wp-content/uploads/2018/06/Manual-Diagnosico-e-Estatistico-de-Transtornos-Mentais-DSM-5-1-pdf.pdf

2. Andrews G, Pine DS, Hobbs MJ, Anderson TM, Sunderland M. Neurodevelopmental disorders: Cluster 2 of the proposed meta-structure for DSM-V and ICD-11. Psychol Med. 2009;39(12):2013–23. http://dx.doi.org/ 10.1017/S0033291709990274

3. Stores G. Multifactorial Influences, Including Comorbidities, Contributing to Sleep Disturbance in Children with a Neurodevelopmental Disorder. CNS Neurosci Ther. 2016;22(11):875–9. http://dx.doi.org/10.1111/cns.12574

4. Demetriou EA, DeMayo MM, Guastella AJ. Executive Function in Autism Spectrum Disorder: History, Theoretical Models, Empirical Findings, and Potential as an Endophenotype. Front Psychiatry. 2019;10:753. http://dx.doi.org/10.3389/fpsyt.2019.00753

5. Pan CY, Chu CH, Tsai CL, Sung MC, Huang CY, Ma WY. The impacts of physical activity intervention on physical and cognitive outcomes in children with autism spectrum disorder. Autism. 2017;21(2):190–202. http://dx.doi.org/10.1177/1362361316633562

6. Faedda N, Romani M, Rossetti S, Vigliante M, Pezzuti L, Cardona F, et al. Intellectual functioning and executive functions in children and adolescents with attention deficit hyperactivity disorder (ADHD) and specific learning disorder (SLD). Scand J Psychol. 2019;60(5):440–6. http://dx.doi.org/10.1111/sjop.12562

7. Fenollar-Cortés J, Gallego-Martínez A, Fuentes LJ. The role of inattention and hyperactivity/impulsivity in the fine motor coordination in children with ADHD. Res Dev Disabil. 2017;69:77–84. http://dx.doi.org/10.1016/j.ridd.2017.08.003

8. Baldi S, Caravale B, Presaghi F. Daily motor characteristics in children with developmental coordination disorder and in children with specific learning disorder. Dyslexia. 2018;24(4):380–90. http://dx.doi.org/10.1002/dys.1595

9. Vuijk PJ, Hartman E, Scherder E, Visscher C. Motor performance of children with mild intellectual disability and borderline intellectual functioning. J Intellect Disabil Res. 2010;54(11):955–65. http://dx.doi.org/10.1111/j.1365-2788.2010.01318.x

10. Westendorp M, Houwen S, Hartman E, Visscher C. Are gross motor skills and sports participation related in children with intellectual disabilities? Res Dev Disabil. 2011;32(3):1147–53. http://dx.doi.org/10.1016/j.ridd.2011.01.009

11. Ament K, Mejia A, Buhlman R, Erklin S, Caffo B, Mostofsky S, et al. Evidence for specificity of motor impairments in catching and balance in children with autism. J Autism Dev Disord. 2015;45(3):742-51. http://dx.doi.org/10.1007/s10803-014-2229-0

12. Licari MK, Alvares GA, Varcin K, Evans KL, Cleary D, Reid SL, et al. Prevalence of Motor Difficulties in Autism Spectrum Disorder: Analysis of a Population-Based Cohort. Autism Res. 2020;13(2):298–306. http://dx.doi.org/10.1002/aur.2230

13. Kaiser ML, Schoemaker MM, Albaret JM, Geuze RH. What is the evidence of impaired motor skills and motor control among children with attention deficit hyperactivity disorder (ADHD)? Systematic review of the literature. Res Dev Disabil. 2015;36:338–57. http://dx.doi.org/10.1016/j.ridd.2014.09.023

14. Ribeiro MS. Preditores do desempenho das atividades de autocuidado, mobilidade e função social em crianças com transtorno do neurodesenvolvimento: um estudo transversal [dissertação] [Internet]. Diamantina: Universidade Federal dos Vales do Jequitinhonha e Mucuri; 2019. Available from: https://www.sgppg.com.br/ppg/ppgreab-programa-de-pos-graduacao-em-reabilitacao-e-desempenho-funcional/2/dissertacao-tese/preditores-do-desempenho-das-atividades-de-auto-cuidado-mobilidade-e-funcao-social-em-criancas-com-transtornos-do-neurodesenvolvimento-um-estudo-transversal/209/

15. Jain M, Passi GR. Assessment of a modified mini-mental scale for cognitive functions in children. Indian Pediatr. 2005;42(9):907–12. Cited: PMID: 16208050

16. Ulrich DA, Sanford CB. Test of Gross Motor Development: Examiner's manual. 2a. Ed. Austin: Prod-Ed; 2000.

17. Valentini NC. Validity and rebility of the TGMD-2 for Brazilian children. J Mot Behav. 2012;44(4):275–80. http://dx.doi.org/10.1080/00222895.2012.700967

18. Ferracioli L. Aspectos da construção do conhecimento e da aprendizagem na obra de piaget. Cad Bras Ens Fís [Internet]. 1999;16(2):180–94. Available from: https://periodicos.ufsc.br/index.php/fisica/article/view/6808

19. Diamond A. Close Interrelation of Motor Development and Cognitive Development and of the Cerebellum and Prefrontal Cortex. Child Dev. 2000;71(1):44–56. http://dx.doi.org/10.1111/1467-8624.00117

20. Piek JP, Dawson L, Smith LM, Gasson N. The role of early fine and gross motor development on later motor and cognitive ability. Hum Mov Sci. 2008;27(5):668–81. http://dx.doi.org/10.1016/j.humov.2007.11.002

21. Houwen S, Visser L, van der Putten A, Vlaskamp C. The interrelationships between motor, cognitive, and language development in children with and without intellectual and developmental disabilities. Res Dev Disabil. 2016;53–54:19–31. http://dx.doi.org/10.1016/j.ridd.2016.01.012

22. Dyck MJ, Piek JP, Hay D, Smith L, Hallmayer J. Are abilities abnormally interdependent in children with autism? J Clin Child Adolesc Psychol. 2006;35(1):20–33. http://dx.doi.org/10.1207/s15374424jccp3501_3

23. Cornoldi C, Giofrè D, Orsini A, Pezzuti L. Differences in the intellectual profile of children with intellectual vs. learning disability. Res Dev Disabil. 2014;35(9):2224–30. http://dx.doi.org/10.1016/j.ridd.2014.05.013

24. Moura R, Andrade PMO, Fontes PLB, Ferreira FO, Salvador LS, Carvalho MRS, et al. Mini-mental state exam for children (MMC) in children with hemiplegic cerebral palsy. Dement Neuropsychol. 2017;11(3):287–96. http://dx.doi.org/10.1590/1980-57642016dn11-030011

25. Paterlini LSM, Zuanetti PA, Pontes-Fernandes AC, Fukuda MTH, Hamad APA. Screening and diagnosis of learning disabilities/ disorders - outcomes of interdisciplinary assessments. Rev CEFAC. 2019;21(5):e13319. https://doi.org/10.1590/1982-0216/201921513319

26. Dias-Viana JL, Gomes GVA. Wechsler Intelligence Scale for Children (WISC): analysis of the production of Brazilian scientific articles. Psicol Rev. 2019;28(1):9–36. https://doi.org/10.23925/2594-3871.2019v28i1p9-36

27. Hyman SL, Levy SE, Myers SM. Identification, Evaluation, and Management of Children With Autism Spectrum Disorder. Pediatrics. 2020;145(1):e20193447. https://doi.org/10.1542/peds.2019-3447

28. Staples KL, Reid G. Fundamental movement skills and autism spectrum disorders. J Autism Dev Disord. 2010;40(2):209–17. https://doi.org/10.1007/s10803-009-0854-9

29. Silveira RA, Cardoso FL, Souza CA. Avaliação do desenvolvimento motor de escolares com três baterias motoras: EDM , MABC-2 e TGMD-2. Cinergis [Internet]. 2014;15(3):140–7. Available from: https://online.unisc.br/seer/index.php/cinergis/article/view/5003