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Original Article

Cognitive level and developmental coordination disorder: study with schoolchildren aged 7 to 10 years old

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Abstract: Introduction: Children with Developmental Coordination Disorder (DCD) have difficulties learning motor tasks, which suggests cognitive alteration, but evidence about the relationship between motor performance and cognitive level are still inconclusive. Objective: To investigate the relationship between the cognitive level and motor performance of children 7 to 10 years old with and without DCD. Method: We evaluated 402 children from public schools with the motor coordination test, Movement Assessment Battery for Children 2nd ed. (MABC-2) and the cognitive test, Raven's Progressive Matrices (Raven). Parents completed the Developmental Coordination Disorder Questionnaire (DCDQ-Brazil), the Brazil Criterion for Economic Classification and a child's health history. Data were analyzed using descriptive statistics and association, comparison and correlation tests. Results: Of the 402 children evaluated, 35 (8,7%) were identified with DCD. No difference was found in cognitive percentiles among children with and without DCD ($p = 0{,}223$), but there was a significant association between motor performance and cognitive level in the DCD group ($p = 0{,}023$), with a trend towards higher cognitive percentiles in the non-DCD group. There was a significant association ($p = 0{,}009$) between the global percentile in MABC-2 and Raven in the total sample. In groups with DCD, there was a significant negative correlation only between MABC-2 and age. Conclusion: There was a greater association between motor and cognitive tests' scores than between DCD and cognitive level. The results reinforce the heterogeneous profile of children with DCD in both motor and cognitive domain.

Keywords: *Developmental Coordination Disorder, Cognition, Child.*

Nível cognitivo e transtorno do desenvolvimento da coordenação: estudo com escolares de 7 a 10 anos de idade

Resumo: Introdução: Crianças com Transtorno do Desenvolvimento da Coordenação (TDC) apresentam dificuldades para aprender tarefas motoras, o que sugere alteração cognitiva, mas evidências sobre a relação entre desempenho motor e nível cognitivo ainda são inconclusivas. Objetivo: Investigar a relação entre nível cognitivo e desempenho motor em crianças de 7 a 10 anos de idade com e sem TDC. Método: Foram avaliadas 402 crianças de escolas públicas com o teste de coordenação motora *Movement Assessment Battery for Children* 2ª ed. (MABC-2) e o teste cognitivo Matrizes Progressivas de Raven (Raven). Os pais preencheram o *Developmental Coordination Disorder Questionnaire* (DCDQ-Brasil), o Critério Brasil de classificação econômica e um histórico de saúde da criança. Os dados foram analisados com uso de estatística descritiva e testes de associação, comparação e correlação. Resultados: Das 402 crianças avaliadas, 35 (8,7%) foram identificadas com TDC. Não foi encontrada diferença nos percentis cognitivos entre crianças com e sem TDC ($p = 0{,}223$), mas houve associação significativa entre desempenho motor e nível cognitivo no grupo TDC ($p=0{,}023$), com tendência para percentis cognitivos mais altos no grupo não-TDC. Houve associação significativa ($p=0{,}009$) entre o percentil global no MABC-2 e o Raven na amostra total. Nos grupos com TDC, houve correlação negativa significante apenas entre o MABC-2 e a idade. Conclusão: Houve maior associação entre as pontuações nos testes motor e cognitivo do que entre TDC e nível cognitivo. Os resultados reforçam o perfil heterogêneo das crianças com TDC tanto no domínio motor como cognitivo.

Palavras-chave: *Transtorno do Desenvolvimento da Coordenação, Cognição, Crianças.*

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1 Introduction

The motor development and the exploration of the environment are the basis of the first learning, necessary for neurological organization and interaction with the environment (BARELA, 2006). From an ecological perspective, the children are seen as active protagonist in the construction of their development, since when exploring the environment, they develop increasingly efficient strategies to deal with their context, and one of the aspects developed in this process is the cognition (LEONARD, 2016).

With adequate stimuli and the absence of biological risk factors, most children develop age-compatible motor skills; however, it is known that 5-6% of the children have motor performance below age expectation with no apparent cause, a condition called Developmental Coordination Disorder (DCD) (AMERICAN..., 2014). According to the Diagnostic and Statistical Manual of Mental Disorders - DSM-5 of the American Psychiatric Association (AMERICAN..., 2014), DCD is a motor deficit detected in childhood, which impairs the performance of tasks that require fine and gross motor skills. Children with DCD have difficulties to perform activities of daily living and participate in school and/or leisure activities, which may contribute to the appearance of secondary emotional and behavioral problems, affecting psychosocial and cognitive development (ZWICKER et al., 2012).

Children with DCD have different levels of motor deficit, combined or not with other disorders, such as attention deficit, language disorder, learning, and psychosocial issues, but the common characteristic among them is the variable, slow, with less acuity motor performance and the difficulty to learn childhood typical motor tasks (GOULARDINS et al., 2015). Although the diagnosis criteria for DCD specify that the motor deficit cannot be better explained by other disorders, such as mental deficiency, the motor learning difficulties, which characterize the disorder, suggest lower cognitive skills (WILSON et al., 2017) even considering that in most studies on DCD, children with intelligence quotient below 70 are excluded (GEUZE; SCHOEMAKER; SMITS-ENGELSMAN, 2015).

Since the last century, Piaget (PIAGET, 1952) has alerted on the way children learn by moving and observing their actions on objects. The support for this relationship between motor and cognitive abilities comes from studies that show that: (a) there is a co-activation of the brain areas related to cognitive and motor processes when the child performs new tasks, requiring attention or effort, (b) cognitive and motor skills seem to emerge at the same time in the development, (c) in addition to sharing similar processes such as planning, sequencing and monitoring (VAN DER FELS et al., 2015).

Although several studies support the association between motor performance and cognitive processes, such as learning and attention, systematic review (VAN DER FELS et al., 2015) on the relationship between motor and cognitive skills in children with typical development, showed that there is not enough evidence to support or refute this relationship. Correlation between cognitive abilities and fine motor coordination, bilateral coordination and temporal performance were found but the correlation with balance, strength, and agility was weak or absent. One problem identified in the review was that the methodologies and measures used were different, hindering to draw objective conclusions. Also, the few studies investigating the cognitive performance of children with DCD (ASONITOU; KOUTSOUKI, 2016; SUMNER; PRATT; HILL, 2016) provide inconclusive information since as already commented by other authors (GOULARDINS et al., 2015), comorbidities are not excluded in many studies, the investigations address neurobiological issues with imaging exams, without specifically focusing on the motor-cognition relationship, the samples are limited and using divergent methodologies.

Considering recent studies on DCD, Asonitou et al. (2012) investigated the cognitive abilities of Greek schoolchildren with and without DCD using the Cognitive Assessment System (CAS) and found worse performance on the planning, attention and simultaneous processing scales in children with DCD. One limitation of this study is that the DCD group was defined only by the motor test (percentile ≤ 6 in the MABC) and the absence of other disorders, but not including a measure of the difficulty in performing daily activities.

Applying full diagnostic criteria, Sumner, Pratt, and Hill (2016) also compared the cognitive abilities of children with and without DCD but using the cognitive test WISC-IV. They observed that the DCD group showed performance within the population mean, but the cognitive profile was heterogeneous, with inferior performance in the DCD group in measures of processing speed and working memory. The authors concluded that because of the heterogeneity in the DCD group, it was not possible to establish a distinct cognitive profile for these children, and recommended analys of individual performance patterns for intervention planning.

In a systematic review on the criteria used for DCD diagnosis, Smits-Engelsman et al. (2015) have identified inconsistencies. Although it is important to rule out the possibility of cognitive deficit to confirm the DCD diagnosis, no reference was found in 57% of the studies reviewed to the intelligence test. There is little information on the impact of the cognitive level on the diagnosis of the disorder, and a cognitive limit should be established as a criterion for diagnosis (SMITS-ENGELSMAN et al., 2015). Based on the data obtained in the different studies, the authors recommend standardizing the criteria, using the 15 percentile for motor tests and Intelligence Quotient (IQ) above 69 as cutoff points for the diagnosis of DCD (SMITS-ENGELSMAN et al., 2015).

In Brazil, only one study on the relationship between cognition and coordination disorder was found. Rocha et al. (2016) investigated the relationship between motor performance, cognitive maturity, and age in 89 children aged 4 and 5 years old of the municipal education network in the city of Maringá (PR). The children had higher mean cognitive maturity and, although a significant low correlation (r = 0.22) between cognition and performance in the MABC-2 test was found, there was no relationship between a possible DCD diagnosis and cognitive maturity.

The evidence on the relationship between motor performance and cognitive level in children with and without motor coordination problems and/or DCD is still inconclusive, requiring further studies with different populations, which may help in the definition of more specific criteria for diagnosis and in planning more effective interventions for these children. The objective of this study was to investigate the relationship between cognitive level and motor performance in children of public schools with different levels of motor performance, with and without DCD.

2 Method

This is a descriptive, cross-sectional study with the recruitment of schoolchildren from an extra school program of physical activities - Second Time Program (*PST*) of the municipal network, to ensure that all children had the opportunity to do physical activities. This research was approved by the Ethics Committee on Research on Human Beings of the Federal University of Minas Gerais (COEP/UFMG - CAE Opinion 54548316.7.0000.5149). The students were evaluated with the consent of the Sports and Education Secretariats of the City Hall of Belo Horizonte, that mediated the contact and provided information about the schools available for the study, which were later selected by draw.

2.1 Participants of the study

Children aged 7 to 10 years old and 11 months, from 21 municipal schools, located in six administrative regions of the city of Belo Horizonte-MG were invited to participate in the study. The sample calculation was based on the number of children attending the *PST* and considering the prevalence rate of DCD of 5%, resulting in recruitment of about 708 children. However, due to the end of *PST* activities in the data collection period, only 600 invitations were distributed. The selection of participants was probabilistic, according to the number of students enrolled in each region, divided into two groups: (1) DCD and (2) Non-DCD.

The DCD Group had children with signs of DCD, classified based on the Movement Assessment for Children - MABC-2 (SUDGEN; HENDERSON; BARNETT, 2007) and the Developmental Coordination Disorder Questionnaire (DCDQ-Brazil) (PRADO; MAGALHÃES; WILSON, 2009). In the absence of Brazilian normative data, the original cut-off points of each instrument were used as criteria. The children included in this group met the four criteria of DSM-5 (AMERICAN..., 2014) for DCD diagnosis: to show significant motor deficits assessed by MABC-2 (Criterion A); these deficits impact on daily living activities and/or academic performance, as reported by parents in DCDQ-Brazil (Criterion B); early childhood, including only school children (Criterion C); and absence of other diagnosed medical or neurological conditions, as reported by their parents, and no intellectual deficit, which could explain the motor disorder (Criterion D). The criteria suggested by Smits-Engelsman et al. (2015) to classify DCD in research were also adopted: children with MABC-2 score ≤ 15 percentile, functional performance below the cut-off point in DCDQ-Brazil (PRADO; MAGALHÃES; WILSON, 2009) and cognitive performance compatible or above the mean age, besides other inclusion/exclusion criteria. For the analysis, a subgroup with a score of MABC-2 ≤ percentile 5, named Severe DCD (DCD-Severe) (SMITS-ENGELSMAN et al., 2015) was identified in the TDC group. Thus, in the results and discussion, DCD is the total group of children with the motor disorder and Severe DCD is the subgroup with higher motor impairment.

The Non-DCD Group had typical children, without complaints of motor difficulties or other developmental disorders. Besides the inclusion criteria described, all children should have had the Informed Consent Form (ICF) signed by their parents or guardian, be enrolled and regular at a school level compatible with their chronological age. Children with diagnoses or signs of motor deficiency, genetic disorder, epilepsy or other comorbidities, such as seizures, neurological or orthopedic problems, history of fracture, surgery or accident in the last six months or who had a score of below-average cognitive level were excluded from the study.

2.2 Instruments

The MABC-2 was used to evaluate motor performance (Criterion A). This is a British test that has a validity study for Brazilian children (VALENTINI; RAMALHO; OLIVEIRA, 2014). MABC-2 was created to identify deficits in motor coordination in children and adolescents aged 3 to 15 years old and it is one of the tests most used as a motor criterion for the diagnosis of DCD (SMITS-ENGELSMAN et al., 2015). The test items are distributed by the level of difficulty in three age groups. In this study, the age group 2, for children aged 7 to 10 years old, was used. The test has eight items, distributed in three components: (1) Manual Dexterity Section - Fine Motor; (2) Ball Skills Section - Gross Motor (3) Static and Dynamic Balance Section - Balance. The raw data are transformed into standardized scores and percentiles, obtained in normative tables by age and interpreted as follows: ≤ 5% means motor deficit, indicative of DCD; percentile of 6 to 15% suggests risk of DCD and percentile ≥ 16% means typical development. In the study by Valentini, Ramalho, and Oliveira (2014) with 844 Brazilian children aged 3-13 years old, MABC-2 showed good test-retest reliability (0.82), internal consistency (0.78) and good discriminant validity (0.80).

The DCDQ was used to evaluate the impact of the motor deficit on daily activities (Criterion B) (WILSON et al., 2000).This questionnaire was created in Canada, and translated and adapted into Brazilian Portuguese, resulting in the DCDQ-Brazil (PRADO; MAGALHÃES; WILSON, 2009). It is a questionnaire for parents, used to detect DCD in children and adolescents between 5 and 15 years old. The DCDQ has 15 items that report motor performance during movement, fine motor/writing, and general coordination. The questionnaire is scored on a five-point Likert scale, with the simple addition of the score of each item to obtain the final score, for a total of 65 points. Cut-off points to detect DCD were set for each age group: 5 to 8 years old (0-46 points), 8 to 10 years old (0-55 points) and 10 to 15 years old (0-57 points). In the study of cross-cultural adaptation with Brazilian children aged 7 to 12 years old (PRADO; MAGALHÃES; WILSON, 2009), the questionnaire presented good test-retest reliability (0.97) and internal consistency (0.96), good sensitivity (0.73), specificity (0.87), and positive (0.73) and negative (0.87) prediction values.

The Raven progressive matrix - RAVEN, standardized for Brazilian children (ANGELINI et al., 1999) ages 5 to 11 years old was administered to evaluate the cognitive level (Criterion D). Raven aims at evaluating general intelligence, defined as the ability to extract meaning, make comparisons and reason by analogy, extrapolating the information provided or previously acquired (MUNIZ; GOMES; PASIAN, 2016). The test has a series of drawings, in ascending order of difficulty, in which a part to be completed is missing. The child must find between six options the complete it. The number of correct items is the final score, transformed into percentiles and interpreted according to the following cognitive levels: I. Intellectually superior - 95 percentile or higher; II. Definitely above the average of intellectual ability - 75 to 94 percentile; III. Intellectually average - 26 to 74 percentile; IV. Definitely below average in intellectual ability - 6 to 25 percentile; V. Intellectually deficient - percentile 5 or below (ANGELINI et al., 1999). The Brazilian Raven has acceptable test-retest reliability (0.69 to 0.85) and high internal consistency (0.88 to 0.93). As it fast and easy to use, RAVEN was used to estimate the cognitive level and to exclude children with the intellectual deficit, that is, levels IV and V.

An interview with the parents was also made through a semi-structured questionnaire, to obtain information about the child's health history, relevant aspects of birth, such as birth weight and history of prematurity, and current issues such as the presence of chronic diseases, physical trauma, and motor therapy. Perinatal data regarding weight at birth and presence of prematurity were included because they are important risk factors for DCD (ZWICKER et al., 2012). The Brazilian Economic Classification Criteria of the Brazilian Association of Research Companies (ASSOCIAÇÃO..., 2016) was applied to estimate the economic level of the families.

2.3 Data collection procedures

In the schools selected, the researchers visited the classrooms and invited the students of the age group intended to participate in the study, giving the Informed Consent Form (ICF). After the parents or guardians signing it authorizing the participation, date and time for the interview was scheduled and data collection started. All the evaluations were carried out in the schools, individually or in groups of three children, in well-lit and non-interfering environments (wide classroom, gym, video room or schoolyard), in shift and schedules previously combined with teachers. The interviews with the parents were scheduled in advance, on the day, place and time of preference of the parents. The total duration of the evaluations (motor and cognitive) was about one and a half hour per student - approximately 40 minutes for the motor test and 30 minutes for the cognitive test, varying according to the students´ ability to perform the tasks. The interviews with the parents ranged from 20 to 30 minutes.

The motor test was applied by a single researcher as well as the cognitive test that was applied by a psychology student, both with specific training. The reliability of the MABC-2 examiner was verified, before the data collection, by joint and independent score with another examiner of 10 videos of the test, ranging from 0.856 (Target) and 0.866 (Tracing) to 1.0 (intra-class correlation index).

2.4 Statistical analysis

Descriptive analysis was performed calculating means, frequencies and standard deviations. The Kolmogorov-Smirnov test was used to verify the normality of data distribution. The Chi-Square and Fisher's exact test were used in the inferential analyzes to verify the associations between the categorical variables and the Kruskal-Wallis test was used for non-categorical data. Spearman correlation was used to verify if there were differences in the pattern of correlation between cognitive level, motor scores, age and variables of interest in the groups with and without DCD. The correlation indices were interpreted as follows: <0.25 - little or no relation, 0.25-0.50 - weak relation, 0.51-0.75 - moderate correlation, and >0.75 - excellent correlation (PORTNEY; WATKINS, 2009). The Statistical Package for Social Sciences (SPSS), version 20.0, and R programs were used, adopting $p < 0.05$ for all the analyzes.

3 Results

Of the 600 children invited to the study, 198 were excluded due to (a) not giving a signed ICF (154 children); (b) no parent/guardian attendance at the interview (38 children); (c) having some of the conditions of the study's exclusion criteria (6 children). The final sample consisted of 402 children, mean age of 110.75 (± 13.22) months, of which 227 (56.5%) were girls. Table 1 shows the sample characterization, according to distribution in the groups with and without DCD.

Thirty-five (8.7%) children with DCD were identified, 25 (6.2%) of them had severe DCD. Differences of gender, with a higher number of boys in the DCD group, were found in the groups. Nine (2.2%) parents could not tell if the child was born prematurely. Fifty-six (13.9%) cases of prematurity

Table 1. Characterization of the sample comparing the groups with and without DCD.

Variables\Motor Disorder		No-DCD		DCD		p
		n	%	n	%	
Sex	Male	151	86.3	24	13.7	**0.002**[1]
	Female	216	95.2	11	4.8	
Economic Classification	A/B1/B2	57	93.4	4	6.6	0.670[1]
	C1	111	92.5	9	7.5	
	C2	133	91.1	13	8.9	
	D-E	66	88.0	9	12.0	
Education level of the head of the family	Incomplete Elementary school	21	81	5	19	0.060[1]
	Complete Elementary school	82	90	9	10	
	Complete Middle school	89	88	12	12	
	Complete High school/ Incomplete Higher Education.	158	95	9	5	
	Complete Higher Education	17	100	0	0	
Prematurity	No	309	91,69	28	8.30	1,000[1]
	Yes	50	89,28	6	10.71	
Age in months (Mean; SD)		110.82	13.37	109.97	11.62	0.552[2]
Weight at birth (Mean; SD)		3.20	0.61	3.16	0.64	0.400[2]

[1] Chi-Square Test. [2] Mann-Whitney test.

were reported, with gestational age at birth varying from 31 to 36 weeks, mean of 34.70 (± 1.62) weeks, characterized mainly (78.57%), by late preterm infants (34 to 36 weeks).

The mean percentile in Raven's cognitive test was 75.76 (± 19.69); 24.1% of the children were classified as intellectually superior, 42.5% as intellectually above the average and 33.3% were classified in average. Considering the groups, the mean percentile of the non-DCD group was 76.58 ± 18.91, the DCD group was 67.23 ± 25.31 and the Severe DCD subgroup was 65.72 ± 26.92, with no significant difference between groups (Kruskal-Wallis, p = 0.223). In Figure 1, the medians and comparative distribution of the DCD and Non-DCD groups in the three cognitive levels of the Raven are shown. The two groups had a heterogeneous cognitive pattern, with children distributed in the three Raven classifications.

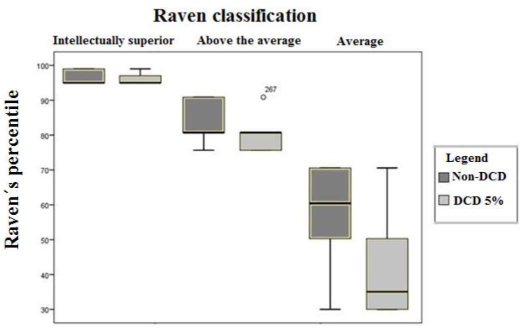

Figure 1. Distribution of the DCD and Non-DCD groups in the Raven's three cognitive levels.

Table 2 shows the frequency of children with motor impairment at the three cognitive levels defined by Raven. There was a significant association between the cognitive level and the presence of DCD (p = 0.041), with a lower percentage of children with intelligence above the mean in DCD group than in the non-DCD group, but this association did not remain in the Severe DCD group. When considering only the motor test, there was a significant association between motor deficit and cognition, when considering the 15 percentile in MABC-2 (p = 0.023), that is, children with motor deficit presented worse results in the cognitive test. When considering only the severe motor deficit (Percentile 5), there was an association between the performance in manual dexterity and the cognitive level (p = 0.050), with students with deficit in manual dexterity presenting lower percentage of individuals with cognitive level above the mean. There was also a marginal association (p = 0.051)

Table 2. Comparison between the frequency of motor deficits considering DCD 5% and 15% and MABC-2 scores in the 5 and 15 percentile at different cognitive levels according to the Raven test.

Variables		Raven						
		Superior		Above the average		Average		p[1]
		n	%	n	%	n	%	
DCD (15%)	No	88	24.0	162	44.1	117	31.9	**0.041**
	Yes	10	28.6	8	22.9	17	48.6	
General MABC-2 (15%)	Normal	63	24.3	121	46.7	75	29.0	**0.023**
	Deficit	35	24.5	49	34.3	59	41.3	
Manual Dexterity	Normal	82	24.9	145	44.1	102	31.0	0.103
	Deficit	16	21.9	25	34.2	32	43.8	
Ball Skills	Normal	60	22.8	117	44.5	86	32.7	0.422
	Deficit	38	27.3	53	38.1	48	34.5	
Balance	Normal	57	23.8	112	46.7	71	29.6	0.070
	Deficit	41	25.3	58	35.8	63	38.9	
Severe DCD (5%)	No	91	24.1	164	43.5	122	32.4	0.137
	Yes	7	28.0	6	24.0	12	48.0	
General MABC-2 (5%)	Normal	81	25.4	141	44.2	97	30.4	0.051
	Deficit	17	20.5	29	34.9	37	44.6	
Manual Dexterity	Normal	91	24.9	159	43.6	115	31.5	0.050
	Deficit	7	18.9	11	29.7	19	51.4	
Ball Skills	Normal	77	24.3	139	43.8	101	31.9	0.398
	Deficit	21	24.7	31	36.5	33	38.8	
Balance	Normal	75	24.5	137	44.8	94	30.7	0.105
	Deficit	23	24.0	33	34.4	40	41.7	

[1]Chi-Square Test.

between the cognitive level and the total MABC-2 score, following the previously described pattern.

When considering only the percentiles in the motor test (Table 3), there was a significant association (p = 0.009) between the Total MABC-2 and the Raven percentile. According to multiple comparisons, the median in the Raven was lower between children who score up to 5 percentile in MABC-2 than in children with a motor percentile above 15. There was also a significant difference (p = 0.021) between the manual dexterity percentile in MABC-2 and the Raven, with children who scored up to the 5 percentile in manual dexterity having lower median on the Raven than children with a percentile above 15.

In the correlation analyzes (Table 4) between the cognitive test and the variables related to motor performance, there was a very low magnitude

Table 3. Comparison between the percentiles in MABC-2 and the percentiles in Raven.

Percentile MABC		n	Mean	SD	Median	p[1]
General	≤5	83	68.72	2.54	75.00	**0.009**
	(6-15)	60	76.08	2.57	80.00	
	> 15	259	78.02	1.11	80.00	
Manual Dexterity	≤5	37	64.38	4.18	75.00	**0.021**
	(6-15)	36	75.75	3.30	80.00	
	> 15	329	77.11	1.03	80.00	
Ball Skills	≤5	85	73.88	2.35	80.00	0.653
	(6-15)	54	76.89	2.87	80.00	
	> 15	263	76.22	1.16	80.00	
Static and Dynamic balance	≤5	96	71.06	2.33	75.00	0.114
	(6-15)	66	75.59	2.47	80.00	
	> 15	240	77.78	1.16	80.00	

SD = standard deviation. [1]Kruskal-Wallis test.

Table 4. Spearman correlation between Raven and MABC-2 percentiles, DCDQ-Brazil score and sample characteristics for groups with different levels of motor performance.

Group and Variable	Raven	MABC-2 Percentile	DCDQ-Brazil	Age (months)	Parents education	Economic classification
Non-DCD Group						
MABC-2 Percentile	**0.137****					
DCDQ-Parents	0.028	**0.144****				
Age/months	-0.015	**0.255****	**0.121***			
Parents Instruction	0.060	0.047	0.095	0.049		
Economic classification	0.87	0.028	0.087	-0.101	**0.494****	
Prematurity	-0.025	-0.028	-0.038	-0.055	-0.056	0.093
DCD Group (15%)						
MABC-2 Percentile	0.250					
DCDQ- Parents	0.270	0.121				
Age in months	0.135	**-0.337***	-0.025			
Parents Instruction	0.009	0.036	**0.353***	-0.028		
Economic classification	-0.194	-0.079	0.011	0.005	**0.391***	
Prematurity	0.003	-0.197	0.123	**0.344***	0.163	-0.158
Severe DCD Group						
MABC-2 Percentile	0.323					
DCDQ- Parents	0.298	0.280				
Age in months	0.169	**-0.452***	-0.093			
Parents Instruction	0.130	0.005	0.379	0.033		
Economic classification	-0.227	0.085	-0.037	0.036	**0.479***	
Prematurity[1]	0.005	-0.257	-0.110	-0.182	-0.236	-0.294

[1]Gestational age at birth, in weeks. **p<0.01. *p≤0.05.

significant positive correlation in the Non-DCD group between the cognitive level and performance in MABC-2, but this correlation was not maintained in the DCD group (general and severe). As expected, there was a significant positive correlation between the two motor measure in the non-DCD group, which also maintained a correlation with age. However, there was a significant negative correlation between MABC-2 and age only in the groups with DCD, indicating that in these groups, the older the children, the worse the performance in MABC-2.

4 Discussion

This study aimed to investigate the relationship between motor coordination and the cognitive level, specifically analyzing the cognitive performance of children with and without motor coordination deficit. In general, a greater association between the motor test results and the cognitive level was found than the association between the presence of DCD and the cognitive level. The characteristics of the sample, the criteria for recruitment and the very heterogeneity of children with DCD may have contributed to this result.

Considering the sample, the frequency of 8.7% of children with DCD and only 6.2% with severe DCD is consistent with international standards (AMERICAN..., 2014; ZWICKER et al., 2012). The highest number of boys with DCD is also reported in other studies (AMERICAN..., 2014; HARRIS; MICKELSON; ZWICKER, 2015), suggesting that the recruitment criteria were adequate. As expected in public schools, predominated families of low socioeconomic level with parents with elementary and middle school education. Considering perinatal characteristics, there was no difference between the groups, not even in the presence of prematurity, as most children were characterized as low-risk preterm, with less possibility of motor development impact, as observed in the correlation analysis.

When comparing the cognitive level of the groups with and without DCD, there was greater variability in the percentiles in the total group with DCD, as indicated by the greater standard deviation associated to the means of the groups with motor deficit. Although there was no difference in the medians of the groups, there was a lower proportion of children in the higher Raven percentiles (51.4%) compared to the non-DCD group (68.1%) (Table 2). It is important to remember that the sample consisted of children with cognitive level within the normal range, evaluated by a test that measures general intelligence, and even though there was a discrete difference between the groups. The data reveal variability in the percentiles,therefore, it is important to be awere of cognitive issues, since some children may have greater difficulty with inferences, analogies and abstract reasoning, which should be considered when selecting intervention procedures. This association was not maintained when the Severe DCD group was analyzed, possibly due to the reduction of the sample and greater heterogeneity in cognitive percentiles.

The heterogeneity in cognitive skills in schoolchildren with DCD was also discussed by Sumner, Pratt, and Hill (2016) that observed that although children with DCD had scores similar to those children without DCD on the full scale of the WISC-IV cognitive test, they presented worse performance in specific areas such as processing speed and working memory. Asonitou et al. (2012) also observed difficulty in specific cognitive areas such as planning, attention, and coding in preschoolers with DCD. As the Raven was utilized in the present study, it was not possible to analyze specific areas of ability, the results only show that fewer children with DCD had above-average cognitive performance.

It is noteworthy that when analyzing the total sample, MABC-2 score, considering the 15 percentile, a significant association between the motor components and the cognitive component was observed, remaining marginally when considering children with the severe motor deficit, when an association between cognition and manual function was also observed (Table 2). In general, among children with better motor performance there was higher frequency of above-average cognitive level. A similar result was obtained when Raven scores of children with different levels of motor performance were analyzed, that is, children without motor deficits had higher cognitive levels than those with severe motor deficits and low manual dexterity (Table 3). Supporting the association between motor performance and cognition and as in the study by Rocha et al. (2016) with Brazilian preschool children, a very low but significant correlation was found between Raven and MABC-2 scores in children without DCD (Table 4).

The relationship between motor and cognitive performance in children with DCD is supported by previous research (ASONITOU et al., 2012; SMITS-ENGELSMAN; HILL, 2012; LEONARD, 2016; HIGASHIONNA et al., 2017). The data in this study are also consistent with the systematic review by Van der Fels et al. (2015), who revealed a greater correlation between cognition and fine coordination than between balance and strength in typically developing children. The association between cognition and manual dexterity can be explained by the fact that fine motor tasks require more conscious attention and planning, activating the dorsolateral region of the prefrontal cortex, which is also activated in cognitive tasks (DIAMOND, 2000).

The DCDQ-Brazil used as a criterion to characterize functional deficit showed no correlation with the cognitive test. Also, although a very low-magnitude significant correlation was found between the MABC-2 percentiles and the DCDQ scores in the Non-DCD group, this correlation was not observed in the DCD groups. That is, although all children with DCD presented functional deficits, the performance was heterogeneous, with no direct association with the motor deficit, as measured by MABC-2. These data suggest body function deficits such as balance, bilateral coordination and manual dexterity, as measured by MABC-2, influence but do not define functional performance. That is, the motor delay is not directly related to the functional outcome, which demonstrates the adaptation ability of these children, as foreseen in the International Classification of Functioning, Disability and Health (CIF) model (ORGANIZAÇÃO..., 2003). Children with severe motor deficits potentially experience greater difficulties in functional performance, but environmental supports and demands from more lenient or more rigorous parents may influence the level of participation in daily tasks as scored by parents.

This variability in DCDQ-Brazil scores leads to question two aspects: First, since all children in the DCD group were selected based on the motor deficit (MABC-2) associated with the functional criterion (DCDQ-Brazil), since the MABC-2 score correlated with the cognitive level and with DCDQ-Brazil, it is possible that this functional criterion contributed to add greater variability or cognitive heterogeneity in the groups with DCD. Second, given the correlation between the DCDQ-Brazil and parents' school level in the DCD group, although DCDQ-Brazil was answered in the interview format, it is possible that some parents, especially those of lower educational level, had difficulty to score the children's functional performance, resulting in the heterogeneity observed in the DCDQ-Brazil scores in the DCD groups. These data suggest the need for more detailed observation of functional performance beyond the questionnaire scored by parents. The combination of information from different sources such as parents and teachers could contribute to better diagnosis of DCD.

In this study, a non-verbal reasoning cognitive test, consisting of separating relevant attributes from the irrelevant ones (ANGELINI et al., 1999); was used to evaluate the general cognitive ability; this approach is different from other studies in which they use instruments with specific subtests to extract information about cognitive areas such as planning, attention coding, language, visual perception, and executive function (WASSENBERG et al., 2005; ASONITOU; KOUTSOUKI; CHARITOU, 2010; WILSON et al., 2013; HIGASHIONNA et al., 2017). The adoption of different cognitive tests in the literature hinders comparisons since there are few studies in which Raven was used with the objective of comparing motor and cognitive abilities. Among the studies on DCD, no study was found for this purpose, using specific Raven.

The negative correlation between age and motor performance in the general and severe DCD groups indicated that the older the age, the worse the motor performance in these groups, differently from the significant and positive correlation in the group of typical children. This data is consistent with longitudinal studies of children with DCD, which show a tendency for less engagement in moderate and vigorous motor activities with age, characterizing a persistent deficit of motor activity, which impacts on physical conditioning and general motor performance (CAIRNEY et al., 2010; TAL-SABAN; ORNOY; PARUSH, 2014).

The results of this study have implications for the diagnosis and intervention programs. Although questionnaires such as DCDQ are regularly used to support the diagnosis of DCD, the use of different sources of information on functional performance, including direct observation, may improve the accuracy of diagnosis, contributing to more accurate rates of DCD prevalence. As already recommended by other authors, it is important to include a cognitive test in the evaluation of children with DCD since the cognitive profile is heterogeneous and may vary from medium to higher, as in the sample studied. Children with median/lower cognitive level may need more support at home and at school, which should also be considered in the intervention. The most recommended approaches for the treatment of children with DCD are the training of activities of the child's interest using motor learning principles and cognitive strategies (SMITS-ENGELSMAN et al., 2018). However, these approaches require the ability to make inferences and logical reasoning, making it important to investigate the impact of the cognitive level on the effects of this type of treatment.

The possibility of worsening motor deficit with age highlights the need to motivate the children with DCD and their parents to engage in sports and physical activities. As discussed by Leonard

(2016), the cognitive level should not be seen as an isolated issue in the characterization of the disorder considering the wide range of cognitive profiles that children with DCD may present, it is necessary to consider the performance of each individual, both intellectual and motor, for more accurate diagnosis and effective intervention.

Although the sample included a considerable number of children, the group of participants with DCD was relatively small, due to the very prevalence of the disorder, similar to international data (AMERICAN..., 2014). This limitation in the sample did not allow intra-group analyzes, which could reveal differences between children with moderate and severe DCD. Also, the difficulty of administering a large number of questionnaires through interview in this specific sample hindered to use of other questionnaires to identify possible comorbidities. The study sample was predominantly of the middle and lower classes due to the collection sites, which limits generalizations. Another limitation was the cognitive test used, that although it has low cost and quick application, it evaluates cognition in general and not by areas of function. Future studies should investigate the relationships between different motor and cognitive abilities in children with DCD to obtain more robust evidence. It is suggested in future studies to compare the cognitive level of children with moderate and severe DCD, and it is important to investigate other ages, especially older children and adolescents. Longitudinal studies are of extreme importance, for the possibility of revealing patterns of performance over time.

5 Conclusion

Although there is an association between motor performance and cognitive level, children with DCD have a cognitive level similar to those with typical development even when presenting severe motor deficit. It is not possible to identify a specific cognitive profile in the DCD group, which was characterized by heterogeneity in the functional and cognitive domains, whithout association with the degree of motor deficit. Cognitive and functional level evaluations should be routinely included in the diagnosis of DCD, and a more objective evaluation or combination of information from different sources on functional performance is recommended. Future research should adopt rigorous criteria in the selection of individuals with DCD, as reported in this study, and it is important to do more in-depth studies on the relationship between different cognitive abilities and motor and functional performance at different ages. Also, the impact of the cognitive level on intervention procedures should be investigated.

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Author's Contributions

Marcella Manfrin Barbacena: She elaborated the project, collected the data, followed up the analysis and drafted the article. Adriana Maria Valladão Novais Van Petten: She collaborated in the development of the project, in the writing and review of the article. Déborah Lima Ferreira: She collaborated in data collecting and recording and writing the article. Lívia de Castro Magalhães: She oriented the study and design of the project, accompanied collection, and data analysis, and contributed in the writing and review of the article. All authors approved the final version of the text.

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