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Research Article

Correlation Between Executive Function Behaviors and Educational Achievement of Children With Developmental Coordination Disorder

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Abstract

Background: Developmental cordination disorder (DCD) is a serious deficit in development of motor coordination, which affects educational achievements and daily life activities to a considerable extent.

Objectives: The present study aimed to investigate correlations between components of executive function and spelling and math performance of 7 - 11-year-old children with DCD.

Materials and Methods: A descriptive-analytic study was conducted on 53 primary school children with DCD. Persian version of motor observation questionnaire for teachers (PMOQ-T) was used to detect DCD. Executive functions and educational achievements of these children were evaluated using behavior rating inventory of executive function (BRIEF) and a researcher-made test, respectively. Results were analyzed through SPSS software (v. 21) and Pearson correlation coefficient.

Results: The findings showed that components of inhibition ($r = -0.27$, $P < 0.05$), working memory ($r = -0.44$, $P < 0.01$) and organization of material ($r = -0.28$, $P < 0.05$) were significantly correlated with the spelling test. And components of inhibition ($r = -0.27$, $P < 0.05$), shift ($r = -0.38$, $P < 0. 01$), working memory ($r = -0.28$, $P < 0.05$), and planning ($r = -.29$, $P<0.05$) were correlated with math test.

Conclusions: The results may help clinicians for early intervention and focus on related components of executive function to improve the educational performance of DCD children. Knowing that executive function skills are associated with these two achievement domains suggests potentiality of targeted math and spelling interventions for DCD children.

Keywords: Developmental Coordination Disorder, Executive Function, Educational Achievement, Spelling, Math

1. Background

Developmental coordination disorder (DCD) is characterized by a marked impairment of motor coordination, which interferes with daily life activities and academic productivity (1). Children with DCD have also problem with cognition, literacy and mathematics acquisition (2). Several Studies show that children with DCD have difficulties with executive function (EF) components including: organization, planning, decision-making, visualization, working memory, goal-directed movements and adjusting the movement speed (3-5).

EF is a set of cognitive operations to conduct novel or difficult purposeful behaviors such as planning, decision making, working memory, error correction, concentration and inhibition (6-8). EF is also associated with insistence on difficult tasks, following school rules, acting against distractions, inhibition of inappropriate behavior and attending classroom activities (9-12). Many researchers point out that working memory and inhibition play a significant role in early academic success of children (13-15).

Michel et al. showed that children with motor coordination impairments had lower pre-academic skills, facing a considerable disadvantage at the beginning of formal schooling (16). Son et al. also revealed that motor coordination may be important to detect children at risk of academic underachievement (17). Despite high average IQ, performance of children with DCD in school is below average (18). Several studies show that such children have many difficulties in reading, writing and spelling (18-20). Educational problems of children with DCD cover a wide range of deficits such as poor handwriting and poor organizational skills. Motor difficulties relate to school performances such as awkward handwriting, immature cutting ability, and poor manipulation skills are also documented (20-22).

The relationship between EF as one of the higher level functions of brain and academic performance is mentioned in numerous articles, but there is an obvious gap in occupational therapy literature (23). Welsh et al. found that growth in EF skills made efficient contributions to educational performance of children (24). Roebers et al. also showed that EF is positively related to academic achievement (25).

In addition, there is poor literature regarding EF across neuro-developmental disorders with respect to DCD, diagnosed on the basis of movement difficulties which interfere with academic achievement or daily activities (1).

With regard to EF difficulties and educational achievement in children with DCD, the current study investigated their correlation and screened children with DCD from normal school population to evaluate them in a real context. Most interventions that address educational problems of such children are based on direct interventions on school performance and basic issues leading to poor academic performance are often overlooked. The current research could study those EF components (including components of behavioral regulation and metacognition index) that are more related to EA; therefore, clinicians will be able to focus on the components in their interventions to improve educational performance of children with DCD and prevent academic problems in pre-school age children with DCD whose educational performance cannot be evaluated.

2. Objectives

The current study aimed to investigate correlations between components of EF (behavioral regulation and metacognition index), spelling and math performance of 7 - 11-year-old children with DCD.

3. Materials and Methods

A descriptive-analytic study was conducted. The research population consisted of primary school children with DCD in Ilam province, Iran, according to Persian version of motor observation questionnaire for teachers (PMOQ-T) and diagnosis of psychiatrists. Inclusion criteria were: age range of 7 to 11 year-old; lack of any neurological, orthopedic, and psychiatric diseases; lack of visual impairment, and having DCD based on PMOQ-T. Exclusion criteria were the unwillingness of the kids or their parents to participate in the study.

The study used multi-stage sampling method. Participants were recruited from eight randomly selected schools from southern and northern areas of Ilam province, Iran. The initial participants were 1002 children selected by convenience sampling method. Based on pilot results and related articles, 50 subject were needed.

After screening via PMOQ-T, scores of students were calculated using researcher-provided norms of PMOQ-T separated for age and gender, and then suspected DCD students were selected. After final diagnosis by psychiatrists, 53 children (32 boys and 21 girls) entered the study. These children were evaluated regarding EF (using behavior rating inventory of executive function (BRIEF) and EA (using researcher-made test). All the parents gave their written informed consents before their children entered the study, which was approved by the Ethics Committee of Iran University of Medical Sciences.

3.1. Persian Version of Motor Observation Questionnaire for Teachers (PMOQ-T)

PMOQ-T is a teacher-made questionnaire to identify children with significant problems in motor activities at school aged 5 to 11 years. PMOQ-T contains 18 items. Internal consistency of questionnaire items is high (a = 0.91). Each item is rated on a four-point scale, from 1: never true for my child to 4:) always true for my child. By adding the scores for each item, the total PMOQ-T score was calculated. Separate norms were developed for age and gender. PMOQ-T was derived from a standardized sample consisting of 505 school boys (26).

3.2. Behavior Rating Inventory of Executive Function (BRIEF)

BRIEF is a rating scale developed to assess executive function. It has two indexes including: Behavioral regulation index (inhibition, shift and emotional control) and metacognition index (initiation, working memory, planning, organization of materials and monitoring). It includes three versions: parent, teacher and self-report. The original two versions (parent, teacher) consisted of 86 items. The Cronbach's alpha coefficients ranged from 0.80 to 0.98 in clinical and normative samples (27). Internal consistency of metacognition index (MI), behavioral regulation index (BRI), and global executive composite (GEC) were high, ranging from 0.94 to 0.98. Test-retest stability ranged from 0.72 to 0.84 over an average three-week period (28). In Iran, validity and reliability of BRIEF were investigated by Salman et al. They proved the reliability of all test items by an internal consistency method above 85 %. The reliability of the test with test-retest reliability method showed that the correlation between scores was above 79 %, representing a good reliability rate. Also, the validity of the test was calculated using content validity index (CVI) and content validity ratio (CVR) methods, showing a good content validity value (29). The total score of BRIEF on basis of the three-point Likert scale was achieved and the raw scores were converted into standard scores.

3.3. Educational Achievement Test

Educational achievement test is a researcher-made test based on the school achievement of children with DCD in math and spelling. To construct this test, two teachers from first to fifth grades (totally 10 teachers) were asked to design 15 math and 30 spelling questions. Questions included easy, moderate and hard questions. To survey the content validity of questions, CVI and CVR methods were used. For this purpose, all designed equations in each grade were presented to 10 other teachers to complete forms related to content validity, including specificity, clarity, simplicity, and necessity for each question. At the end, 15 math and 30 spelling questions approved on the above basis were presented to the students as EA test. Students' scores in math and spelling test were based on their marks in these two tests.

3.4. Data Analysis

Descriptive statistics (means, standard deviation and percentages) described the study participants and main variables. SPSS ver. 21.0 and Pearson correlation coefficients explored possible correlations between EF and EA. To facilitate the analyses, raw scores were first converted to standard scores using the researcher-provided norms.

4. Results

Table 1 summarizes the basic characteristics of children with DCD.

Table 1. The Basic Characteristics of Children With Developmental Coordination Disorder (n = 53)[a,b]

Variables	Girls (n = 21)	Boys (n = 32)
Age, mo	106.23 ± 16.16	111.56 ± 16.86
Laterality		
Right	16 (30.1)	28 (52.8)
Left	5 (9.4)	4 (7.5)
Grade		
First	5 (9.4)	5 (9.4)
Second	3 (5.6)	6 (11.3)
Third	6 (11.3)	5 (9.4)
Forth	4 (7.5)	10 (18.8)
Fifth	3 (5.6)	6 (11.3)

[a]Values are expressed as mean ± SD or No. (%).
[b]Percent of total sum.

One-thousand and two students participated in the study (499 boys and 503 girls); 53 children (32 boys and 21 girls) had DCD. Forty four children were right-handed (16 girls and 28 boys) and nine children were left-handed (5 girls and 4 boys). The participants aged 7.02 - 11.66 years old. The mean age was 9.12 years (SD = 1.39). The number of students in each grade is shown in Table 1.

4.1. Performance of Children With DCD in BRIEF and Educational Achievement Tests

Table 2 presents the mean and standard deviation values of the performance of the children with DCD based on BRIEF and EA tests.

Table 2. Mean and Standard Deviation of the Performance of Behavior Rating Inventory of Executive Function, Spelling and Math Tests (n = 53)

	Mean ± STD	Upper Limit of 95% Confidence Interval	Lower Limit of 95% Confidence Interval
Inhibition	53.86 ± 8.33	56.16	51.57
Shift	55.39 ± 10.04	58.16	52.62
Emotional control	56.00 ± 10.75	58.96	53.03
Behavioral regulation index	55.92 ± 8.69	58.32	53.52
Initiation	59.92 ± 10.67	62.86	56.98
Working memory	49.22 ± 9.04	51.71	46.73
Planning	49.69 ± 8.89	52.15	47.24
Organization of material	50.39 ± 9.90	53.12	47.66
Monitoring	49.13 ± 11.17	52.21	46.05
Metacognition index	53.20 ± 9.29	55.76	50.64
BRIEF**	53.54 ± 7.99	55.75	51.34
Spelling	11.88 ± 6.73	13.74	10.02
Math	5.16 ± 3.13	6.03	4.30

Abbreviations: BRIEF, behavior rating inventory of executive function; STD, Standard deviation.

4.2. Correlation Among BRIEF, Spelling and Math Tests

Table 3 presents Pearson correlation between scores on the BRIEF (and its components), spelling and math tests.

According to Table 3, correlation between total score of BRIEF and spelling was not significant ($r = -0.25$, $P = 0.06$); scattering of data on this correlation is displayed in Figure 1. But the correlation between BRIEF and math test was significant ($r = -0.34$, $P < 0.05$). Figure 2 shows the scattering of data regarding the correlation between scores on BRIEF and math tests.

4.3. Correlation Between Components of BRIEF and Spelling Test

Table 3 presents the correlation between components of BRIEF and spelling test. The correlations between spelling test and inhibition ($r = -0.27$, $P < 0.05$), BRI ($r = -0.27$, $P < 0.05$), working memory ($r = -0.44$, $P < 0.01$), and

Table 3. Correlation Among Scores on the Behavior Rating Inventory of Executive Function, Spelling and Math Tests in Children With Developmental Coordination Disorder (n = 53)

		Spelling	Math
Inhibition	Pearson correlation	-0.271[a]	-0.278[a]
	P value	0.050	0.044
Shift	Pearson correlation	-0.237	-0.387[b]
	P value	0.088	0.004
Emotional control	Pearson correlation	-0.126	-0.153
	P value	0.371	0.276
Behavioral regulation index	Pearson correlation	-0.273[a]	-0.330[a]
	P value	0.048	0.016
Initiation	Pearson correlation	0.174	-0.136
	P value	0.212	0.332
Working memory	Pearson correlation	0.447[b]	0.289[a]
	P value	0.001	0.036
Planning	Pearson correlation	-0.231	-0.295[a]
	P value	0.097	0.032
Organization of material	Pearson correlation	-0.284[a]	-0.216
	P value	0.039	0.120
Monitoring	Pearson correlation	-0.075	-0.132
	P value	0.594	0.346
Metacognition index	Pearson correlation	-0.149	-0.293[a]
	P value	0.286	0.033
BRIEF	Pearson correlation	-0.259	-0.343[a]
	P value	0.061	0.012

[a]Correlation is significant at the 0.01 level (2-tailed).
[b]Correlation is significant at the 0.05 level (2-tailed).

organization of material ($r = -0.28$, $P < 0.05$) were significant. There were no correlations between the components of shift, emotional control, initiation, planning, monitoring and MI and the spelling test.

4.4. Correlation Between Components of BRIEF and Math Test

Table 3 presents correlation among the components of BRIEF and math test. There were significant correlations between math test and inhibition ($r = -0.27$, $P < 0.05$), shift ($r = -0.38$, $P < 0.01$), working memory ($r = -0.28$, $P < 0.05$), and planning ($r = -0.29$, $P < 0.05$). In addition, correlation values between BRI ($r = -0.33$, $P < 0.05$), MI ($r = -0.29$, $P < 0.05$), and math test were also significant. There were no correlations among components of emotional control, initiation, organization of material, monitoring and the math test.

5. Discussion

Children with DCD are at considerable risk of school failure, and attention to both motor and academic areas is necessary to improve academic performance in this population (19). These children also have difficulties with EF (3-5). Many studies show that EF has an important and basic role in successful participation in school activities and school achievement, but in spite of the wide range of studies on DCD, no study is done on the correlation between EF and school performance in children with DCD. Furthermore, in previous studies, the grade-point average (GPA) of final exams was used to measure students' academic performance; however, in the current study, a researcher-made test was used to measure the spelling and math performance. In addition, BRIEF test used in the current study assessed the real-life behavioral manifestations of executive dysfunction; accordingly, the results could be used to

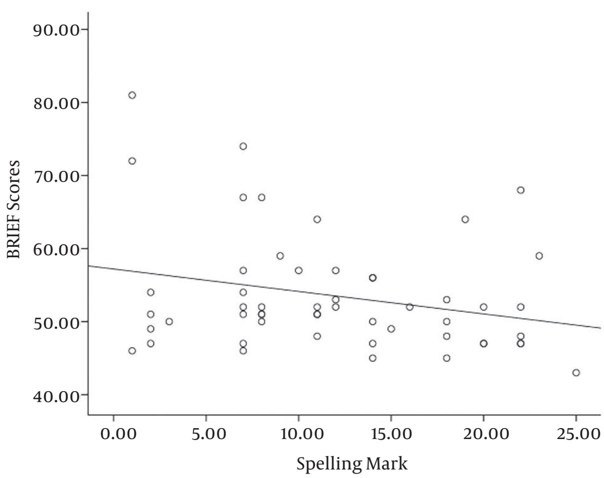

Figure 1. The Scattering of Data About Correlation Between Standard Score of Behavior Rating Inventory of Executive Function and Spelling Marks

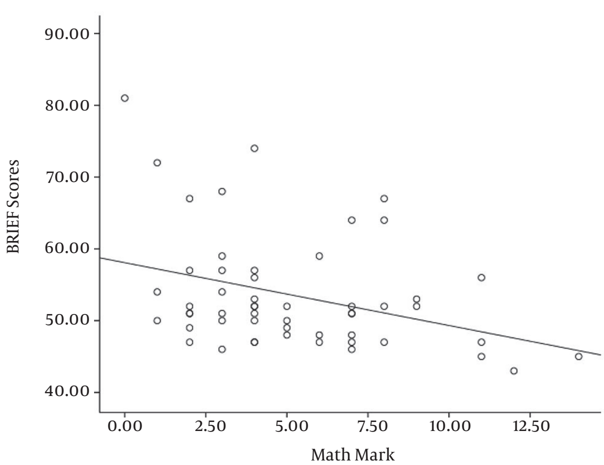

Figure 2. The Scattering of Data About Correlation Between Standard Score of Behavior Rating Inventory of Executive Function and Math Marks

improve everyday living performance of these children.

Unlike many literatures on the significance of correlation between EF and spelling and literacy, in the current study, the general score of EF was not significantly correlated with that of spelling. This disparity across the current study and previous studies could be due to the different nature of DCD. Since motor deficits are the most important characteristics in this population and many studies show that motor problems and educational issues correlate (30-32), it seems that motor problems are more fundamental and relevant to spelling performance of children with DCD.

Nonetheless, the findings of the current study on the correlation between EF and mathematics are consistent with those of the previous research results (33-35). BRIEF test used in the current study measured EF as a higher brain function in the form of problem-solving in everyday activities; solving math problems requires cognitive processes (such as thinking, working memory, and problem solving), hence, both possess a cognitive nature and are related.

5.1. Correlation Between Components of EF and Spelling Performance of Children With DCD

Components of EF correlating with spelling performance were inhibition, working memory (WM) and organization of material. In addition, correlations between BRI and spelling test were also significant. There were no significant correlations among components of shift, emotional control, initiation, planning, monitoring, MI and the spelling test.

The significant correlation between inhibition and spelling performance was consistent with those of the study by Blair et al. they reported that inhibitory control skills in kindergarten predicted early literacy skills in children (33). In addition, Barkley revealed that inhibition is effective in children's educational achievements (36). Altemeier et al. confirmed that inhibition is related to reading and writing skills (37).

A significant correlation was observed between working memory and spelling performance. Significant correlations between working memory and spelling were documented in many studies (38, 39). Working memory is the ability to maintain information in mind, which is empirically related to children's academic and intellectual performance. Hongwanishkul et al. found that assessments of pre-school children's working memory were meaningfully correlated to their overall intellectual functioning (40). Lesaux et al. revealed that working memory in kindergarten was a significant predictor of reading comprehension in the fourth grade (41).

Organization of material was also associated with spelling. Langberg et al. showed that organization abilities are prominent aspects of EF which may affect academic functioning (42).

5.2. Correlation Between Components of EF and Math Performance

The aspects of EF correlating with math performance include: inhibition, shift, working memory and planning. In addition, correlations between BRI and MI and math performance were significant. There were no correlations between components of emotional control, initiation, organization of material, and monitoring and the math test.

These findings were consistent with those of many research works that indicated strong associations between academic ability, inhibition (33), organization, planning and initiation with math (43).

Swanson et al. indicated that working memory contributes to mathematics performance in children in early elementary, even after controlling for their skills such as calculation, processing speed and phonological processing (44). Geary et al. confirmed that mathematics skills are closely related to working memory (45). Passolunghi et al. also found that children's working memory is correlated with their math skill in early primary school (46).

In the current study, inhibition was related to math performance. Inhibition is the ability to maintain irrelevant or distracting information from interfering with performance; it is also important to children's school achievement. Blair et al. reported that children's inhibitory skills measured in preschool predicted their kindergarten skills in mathematics skills (33). According to Bull et al. shifting, working memory and inhibition accounted for unique variance in mathematics performance (47).

Math performance of the students also correlated with planning, which was in line with the study by Gernsbacher et al. in which planning played an important role in academic achievement (48).

In addition, Visu-Petra et al. found that inhibition, shift and working memory are the most important components of EF predicting educational performance (49), which was consistent with the findings of the current study. Furthermore, Welsh et al. demonstrated that calculation and geometric activities in pre-school children require the shifting of attention between components of question (24).

The present study confirmed the existing evidence that executive functions of working memory and inhibition play a decisive role in either spelling or math performance of children with DCD. There are a number of possible reasons for this. Children with poor working memory make frequent mistakes in some educational activities including remembering and performing instructions, keeping track of places in classroom tasks, carrying out mental arithmetic, and writing sentences while formulating texts (48). Furthermore increasing working memory capacity enables children to reflect on a rule deliberately (50), which is probably useful for many educational performances such as counting a string of numbers or learning the order of word letters. The ability to inhibit prepotent responses is beneficial in academic situations which involve extraneous or distracting information (51). For instance, inhibition may be required to discriminate between letters or numbers when learning counting or the alphabet. Inhibition may influence literacy and math performances when children have a larger knowledge base, making the inhibition of task-irrelevant information challenging or when they face more complex tasks such as complicated arithmetic problems (52).

Some of the educational activities need simultaneous processing and storage of information. Several activities clearly involve executive functions such as shifting and inhibition. For example, when the child is writing a sentence in spelling task, there is a complex hierarchical structure that requires shifting between lower levels of processing (identifying the constituent letters in individual words and writing them) and higher levels of activity (such as keeping the surface form of the sentence and identifying the next word in the sequence). Inhibition of irrelevant information is also required in reading a sentence (48, 53).

Consequently, the current study findings bring additional support to the need to include EF assessment as part of formal school evaluations, using proper instruments which tap the multidimensional nature of this construct.

5.3. Implications

The present findings provide evidence for occupational therapists to address EF issues in their interventions and adaptations in schools regarding children with DCD, such as providing a quiet place to play or learn new skills, limit unstructured time, give clear and short instructions, break classroom activities into several steps, plan school activities on the same day and week, organize the movement sequences involved in the tasks, and generally increase the awareness of teachers, caregivers, and children to their educational requirements.

To enhance students' educational performance, students should be able to inhibit ineffective or irrelevant behaviors, represent information in working memory, organize materials and time, plan for future tasks, engage in purposeful activities, and shift fluently from one task to another.

Occupational therapists need to broaden their assessment and intervention regarding children with DCD, focus to include executive functions, specifically those components related to EA, along with the traditional emphasis on motor coordination. Clinicians should include systematic strategies to teach children to perform executive functions.

5.4. Limitations

As the first limitation, the study lacked a normalized tool to evaluate academic achievement in Iran.

The second limitation was that the data on the EF of children with DCD were based on reports by their parents. Parents normally tend to be less than forthcoming in rating their children's weaknesses. A multi-method and/or multi-source model is recommended for future studies. Interviews with students, teachers, and families may aid gathering more comprehensive information concerning the students' functioning level.

5.5. Conclusions

The results of the current study could be used by clinicians for early intervention and improvement of educational performance of children with DCD. Improved understanding of the children with DCD in everyday activities such as school performances is essential to support diagnostic criteria and guide interventions. Clinical decisions about intervention strategies for children with DCD and relevant outcomes concerning activities and participation are required to be based on empirical evidence.

Future research is needed to explore the contribution of other factors such as motor, environmental, emotional, social and psychological parameters on school achievements of children with DCD.

A better understanding of EF and the relationship between EF and EA in such children might be of clinical relevance. The established relationships might suggest that EF skills may improve children's educational skills and be beneficial for their problem solving skills or vice versa. Therefore, the findings highlight the importance of supporting children with DCD in their educational and cognitive development.

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Footnotes

Authors' Contribution: Shirin Maleki: data collection, drafting, writing and submitting the manuscript; Mehdi Alizadeh Zarei: drafting, editing the manuscript and data analysis.

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