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RESEARCH ARTICLE

Motor skills in children with specific learning disorder: A controlled study

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ABSTRACT

Objective: This study aimed to compare the motor skills of children with specific learning disorders (SLD) with those of typically developing children, controlling for attention deficit hyperactivity disorder (ADHD) symptoms. Second, we aimed to examine the relationship between motor skills and children's academic achievement.

Method: The sample consisted of 57 children with SLD (63.2% males, mean age=9.52±0.94), and 30 children as a control group (66.7% males, mean age=9.68±1.08). Wechsler Intelligence Scale for Children-Revised, Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version, Purdue Pegboard Test (PPT), Developmental Coordination Disorder Questionnaire (DCDQ'07), and Swanson, Nolan and Pelham Scale-IV (SNAP-IV) were used.

Results: Of children with SLD, 87.7% had any comorbid psychiatric disorder, mainly ADHD (78.9%). The SLD group had lower scores on both the DCDQ'07 total score and all subtests, but the statistical difference remained only in the DCDQ'07 total score and Fine Motor and Handwriting (FMHW) subtest after controlling for the SNAP-IV scores. Children with SLD scored lower than the control group on the nondominant hemisphere and assembly subtests of PPT, and significant differences remained after controlling for SNAP-IV scores. Academic achievement and motor skills were not correlated in the SLD and control groups, but the FMHW subtest showed the strongest correlation ($r=0.618$, $p<0.001$) with the grade point average in the entire sample. SNAP-IV total score and having an SLD diagnosis were predictive of the DCDQ'07 total score according to regression analysis.

Conclusion: Many children with SLD suffer from motor skill problems, and comorbid ADHD symptoms contribute significantly to them.

Keywords: Academic achievement, attention deficit hyperactivity disorder (ADHD), developmental coordination disorder (DCD), motor skill, specific learning disorder (SLD)

INTRODUCTION

Specific learning disorders (SLD) are defined as academic skills and learning performance that are significantly below what would be expected according to the individual's age and education. SLD causes impairments in one or more domains such as reading, writing, mathematics, language, and reasoning (1). The lifetime prevalence of SLD is reported to be approximately 10%, while this rate is as high as 30% in clinical groups (2). Commonly, SLD is associated with other neurodevelopmental and psychiatric disorders.

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Attention deficit hyperactivity disorder (ADHD), anxiety disorder, and developmental coordination disorder (DCD) are among the most common associated comorbidities (3,4).

Although SLD is diagnosed despite difficulties in the academic area, daily living skills and occupational and social relationships continue to be severely impaired due to information processing difficulties (5). One of the domains known to be impaired in individuals with SLD is motor skills. Motor skills involve sensory input and cognitive processes that affect movement systems beyond the body's movement in space. Difficulties in fine and gross motor skills limit many functions, including participation in games with peers that involve movements such as running, jumping, holding a pencil, writing, and self-care. It has been reported that 40%–57% of children with learning disabilities have problems with motor coordination (6). Evidence suggests that motor skills and cognitive functions are closely related because the same regions of the central nervous system, such as the cerebellum, basal ganglia, and prefrontal cortex, are interconnected (7). Moreover, the cerebellar hypothesis describing the dysfunction of the cerebellum, which plays an essential role in motor control, automation of learned tasks, and speech, provides a common etiological basis for the strong relationship between motor skills and learning (8). Supporting the relationship between cognitive and motor skills, evidence has been suggested that well-developed motor skills in the early life predict learning in areas related to academic achievements such as reading, mathematics, and language (9,10), but the assessment of motor skills in children with academic difficulties remains an underestimated clinical practice. Cognitive and motor skills are thought to be affected together rather than being affected in isolation in neurodevelopmental disorders that occur under the influence of genetic and environmental factors (7). Therefore, impairment in motor skills is one of the overlapping symptom complexes in neurodevelopmental disorders such as ADHD (11), autism (12), and especially DCD (13,14). In particular, the frequent comorbidity of SLD, DCD, and ADHD contributes to motor skill deficits in SLD and complicates the interpretation of results (11,15,16).

Fine and gross motor skills, which are critical to many aspects of life, are expected to be developed in early childhood. Gross motor skills are suggested to increase social competence through participation in games and sports activities, while fine motor skills are associated with academic skills (17,18). Children with motor coordination problems are at risk of having low self-esteem, being ostracized by peers, and developing emotional–behavioral problems (19). Furthermore, it has been reported that children with SLD have a high probability of internalizing and externalizing problems, and families perceive children with SLD as more difficult children compared with children with ADHD (20). Considering the frequency of motor difficulties in children with SLD, it may be conceivable that motor difficulties would have a cumulative adverse effect on the quality of life of these children and their families. Therefore, early identification of children at risk is of clinical importance to ensure appropriate care and prevent secondary outcomes.

In addition to studies comparing motor skills between diagnostic groups separately in the literature (11,21–23), we aimed to evaluate multifactorial associations by considering the overlapping symptom clusters of neurodevelopmental disorders in a relatively large SLD group. For this purpose, our study compared the daily motor coordination characteristics and manual dexterity of children with SLD and children with their typically developing peers considering ADHD symptoms and examined the possible relationships between motor skills and academic achievement. In addition, predictors for motor problems were investigated using multivariable analysis. Based on previous findings regarding biological and behavioral associations between learning and motor skills, we hypothesized that (i) even after controlling for ADHD symptoms, children with SLD would have worse motor coordination and manual dexterity than their typically developing peers, (ii) motor skills would be more strongly associated with academic achievement in children with SLD compared with typically developing children, and (iii) SLD and ADHD would be predictive for motor skills deficit according to multivariable analysis.

METHOD

Participants

Ninety-seven patients diagnosed with SLD aged 8–12 years with a total IQ score of 70 and above who presented to the Child and Adolescent Psychiatry Outpatient Clinic of Marmara University Pendik Research and Training Hospital between 2020 and 2021 were invited to our study. The exclusion criteria of our study included children with intellectual disability, autism, psychotic disorders, neurological disorders (e.g., cerebral palsy and head trauma), and sensory deficits (vision and hearing). The participants and their families were informed in detail about the study, and 57 patients volunteered to participate in the study group. To ensure socioeconomic similarity, 30 age- and gender-matched children from schools in the region where our hospital is located, without academic difficulties and with typically developed, were included in our study as a comparison group. Written informed consent was obtained from the participants and their families that they voluntarily agreed to participate in the study. Clinical interview to diagnose SLD consists of the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM 5) based psychiatric examination by a child and adolescent psychiatrist involving a detailed history, family interview, teacher's information, and reading, writing, and math skills assessed using texts appropriate to age and grade level. Those who had comorbid ADHD and were on medication (only psychostimulant, there was no atomoxetine user in the study group) were asked to discontinue their medication 48 h before the day of the study test to not affect their performance. Psychostimulants have short half-lives (24). Similarly, in the studies in which performance-based measurements are used in children with ADHD, it is a common practice to discontinue the drugs before the test (varying 1–7 days) to exclude the impact of the psychostimulants on performance (25–27). The Clinical Research Ethics Committee of Marmara University Faculty of Medicine approved the study (09.2021.1017).

Assessment Tools

Sociodemographic Data Form

This form prepared by the researchers included information such as age, gender, socioeconomic characteristics, and grade point average (GPA) of the child. Academic achievement was represented by GPA, the cumulative average of all grades in academic subjects. We used the GPA of the participants at the end of the previous semester in our study. Of note, GPA is scored between 0 and 100 points in Turkey. A yes/no question was used to assess parents' awareness level of the impact of motor skills on functionality: "Do the motor problems you observe in your child affect his or her participation in daily activities, academic achievement, and peer relationships?"

Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version (K-SADS-PL)

It is a semistructured diagnostic interview developed to identify past and present psychopathologies of children and adolescents according to the diagnostic criteria of DSM-III and DSM-IV (28). It was translated into Turkish, and its validity and reliability were investigated (29).

Wechsler Intelligence Scale for Children-Revised (WISC-R)

The test was developed to determine the intelligence level of children aged 6–16 years by Wechsler in 1949 and the revised one was developed in 1974 (30,31). The scale was adapted into Turkish by Savasir and Sahin (32).

Swanson, Nolan and Pelham Scale-IV (SNAP-IV)

It was developed considering DSM-IV to assess ADHD symptoms (33). There are nine items for inattention (SNAP-I) and nine items for hyperactivity/impulsivity (SNAP-H/I). SNAP is used in population studies to identify children with probable ADHD (34). No Turkish validation study for SNAP-IV has been published yet; however, it is widely used in Turkey with mean thresholds similar to those used in the world (34–36).

Developmental Coordination Disorder Questionnaire (DCDQ'07)

It was developed by Wilson et al. (37) to assess the coordination skills of children aged 5–15 years in activities of daily living. This questionnaire is divided into three subscales: Control during Movement (CDM), Fine Motor and Handwriting (FMHW), and General Coordination (GC). For each item, parents are asked to compare their children's motor performance with that of children of the same age and rate them on a 5-point Likert scale. The questions relate to how the child plays outside, runs, throws, catches, draws, and writes. The total score of the questionnaire is evaluated using a point scale that corresponds to the child's chronological age. If the total score in the appropriate age group is below the cutoff value, it is interpreted as "Indication of, or Suspect of, DCD" (37). The translation and adaptation study of the scale for Turkish culture was performed with high internal consistency (38).

Purdue Pegboard Test

Children's manual skills, including fine motor skills, are assessed using the Purdue Pegboard Test (PPT). The PPT, developed by Tiffin, has good predictive power and validity. It includes four subtests: the dominant hand (DH), the nondominant hand (non-DH), both hands (BH), and the assembly (Ass) subtest (39). In the DH and non-DH subtests, participants are asked to insert as many sticks as possible into the holes with one hand within 30 s. In the BH subtest, participants must use both hands in a coordinated manner to insert the sticks into both holes within 30 s. In the Ass subtest, participants must independently take and place sticks, washers, and collars with both hands for 60 s. The number of items placed on the board within the time limit represents the

Table 1: Comparisons of WISC-R, SNAP-IV, DCDQ'07, and PPT scores between the groups

	SLD group (n=57) Mean±SD	Control group (n=30) Mean±SD	Test statistic p-value
WISC-R			
Verbal	84.29±13.09	109.86±16.90	t=-7.681, p<**0.001**
Performance	105.30±13.07	127.82±21.12	t=-5.236, p<**0.001**
Total score	94.14±11.73	120.24±17.71	t=-7.147, p<**0.001**
SNAP-I	13.68±4.89	5.56±5.58	t=7.002, p<**0.001**
SNAP-H/I	11.22±6.73	5.83±4.50	t=4.447, p<**0.001**
SNAP-IV Total	24.91±10.13	11.40±8.10	t=6.312, p<**0.001**
DCDQ'07 CDM	21.40±6.20	26.46±3.23	t=-8.440, p<**0.001**
DCDQ'07 FMHW	11.80±4.19	17.96±2.59	U=182.500, p<**0.001**
DCDQ'07 GC	17.03±5.19	20.60±4.51	t=-3.179, p=**0.002**
DCDQ'07 total	50.24±13.12	65.03±8.68	t=-6.286, p<**0.001**
PPT DH	13.08±2.04	13.93±2.57	U=690.00, p=0.135
PPT non-DH	19.22±3.60	18.60±3.11	U=562.500, p=**0.008**
PPT BH	11.66±1.81	13.13±3.10	U=757.500, p=0.373
PPT Ass	17.35±9.10	23.50±7.96	U=598.500, p=**0.002**

Bold values represent p<0.05. PPT: Purdue Pegboard Test; DH: Dominant hand; non-DH: Nondominant hand; BH: Both hands; Ass: Assembly; DCDQ'07: Developmental Coordination Disorder Questionnaire; CDM: Control during movement; FMHW: Fine motor and handwriting; GC: General coordination; SLD: Specific learning disorders; SD: Standard deviation.

score for the subtest. Low scores represent poorer performance because the score indicates how quickly and accurately the sticks are placed in the holes.

Analysis

All statistical analyses were performed using the SPSS 22.0 program. The chi-squared (χ^2) test was used to compare the categorical variables, and Student's t-test and the Mann–Whitney U-test were used to determine the differences between the continuous variables between the groups according to the Kolmogorov–Smirnov test, which was used to evaluate whether the distribution of the variables was normal. The SLD group had significantly higher SNAP-IV scores than the control group; this was controlled by analysis of covariance (ANCOVA) for group statistics when comparing DCDQ'07 and PPT scores between groups. Correlations between academic achievement (GPA) and motor skills (DCDQ'07 and PPT) were evaluated using Pearson's and Spearman's correlation analysis according to normality distribution of variables. Multiple linear regression with backward selection was used to examine the relationship between DCDQ'07 scores and ADHD traits, age, gender, WISC-R total score, and SLD diagnosis. Preliminary analyses were conducted to ensure that the assumptions of normality, linearity, multicollinearity, and homoscedasticity were not violated. A value of p<0.05 was considered statistically significant in all analyses.

RESULTS

Demographic and Clinical Characteristics of Participants

A total of 87 children (i.e., 57 in the SLD group and 30 in the control group) were included in the study. SLD (9.52±0.94, min–max=7.83–11.33) and control (9.68±1.08, min–max=8.25–13.96) groups were similar in terms of mean age (p=0.460, t=-0.723). Of the total children, 63.2% in the SLD group (n=36) and 66.7% in the control group were males (n=20) (χ^2=0.106, p=0.745).

In the SLD group, 41 (71.9%) children were diagnosed with dyslexia, 47 (82.5%) children were diagnosed with dysgraphia, and 16 (28.1%) children were diagnosed with dyscalculia. Of the children in the SLD group, 87.7% (n=50) had at least one comorbid diagnosis. The rates of current comorbid diagnoses of SLD cases were as follows: 78.9% ADHD, 15.8% oppositional defiant children, 3.5% major depressive disorder, 1.8% panic attacks, 12.3% separation anxiety, 14% social phobia, 31.6% specific phobia, 8.8% generalized anxiety disorder, 7.8% obsessive–compulsive disorder, 12.3% enuresis, 8.8% tic disorders, and 3.5% speech sound disorders.

WISC-R and SNAP-IV scores of the sample are presented in Table 1.

Table 2: Comparison of mean DCDQ'07 and PPT scores between groups after controlling for the effect of SNAP-IV total score

	SLD group Mean±SD	Control group Mean±SD	Statistical analysis[a]	
			F	p
PPT				
DH	13.08±2.04	13.93±2.57	2.621	0.109
non-DH	11.66±1.81	13.13±3.10	10.465	**0.002**
BH	19.22±3.06	18.60±3.11	0.652	0.422
Ass	17.35±9.10	23.50±7.96	4.111	**0.046**
DCDQ'07				
Total score	50.24±13.12	65.03±8.68	6.306	**0.014**
CDM	21.40±6.20	26.46±3.23	2.187	0.143
FMHW	11.80±4.19	17.96±2.59	20.571	<**0.001**
GC	17.03±5.19	20.60±4.51	0.514	0.475

Bold represented p<0.05; a: Analysis of covariance (covariate: SNAP total score); PPT: Purdue Pegboard Test; DH: Dominant Hand; nonDH: nonDominant Hand; BH: Both Hands; Ass: Assembly; DCDQ'07: Developmental Coordination Disorder Questionnaire; CDM: Control during movement; FMHW: Fine Motor or Handwriting; GC: General Coordination; SLD: Specific learning disorders; SD: Standard deviation.

Comparison of Motor Skills and Hand Dexterity between Groups

When DCDQ'07 scores were compared, there were significant differences between the groups in DCDQ'07 total score and all subtests (Table 1). Due to the high rate of ADHD comorbidity in the SLD group, comparisons were performed controlling for the SNAP-IV total score, and differences between groups were limited to DCDQ'07 total scores and FMHW subtest scores (Table 2).

Among PPT subtests, there were significant differences in non-DH and Ass subtest scores between the groups (Table 1), and these remained after performing a covariance analysis to control for SNAP-IV total score (Table 2).

The parents of the children reported that 36.8% of the children in the SLD group (n=21) and 6.7% of the children in the control group (n=2) suffered from motor skill problems that limited their activities of daily life (χ^2=9.203, p<0.05). Of the children, 70.2% (n=40) in the SLD group and 23.3% (n=7) in the control group were "suspect of DCD" according to the age-appropriate cutoff scores of the DCDQ'07 (p<0.001, χ^2=17.363). Parents of 20 of the 40 children who were "suspect of DCD" according to the DCDQ'07 in the SLD group answered "yes" the question of whether their children's motor skill problems had a limiting effect on their daily lives before administering the DCDQ'07. Of the 7 subjects who were "suspects of DCD" in the control group, the parent of only 1 child answered "yes" to this question.

Correlations between Motor Skills and Academic Achievement

When examining the correlations between academic achievement and motor skills in the groups separately, no statistically significant relationship was found between the GPA and the DCDQ'07 and PPT scores in either the SLD group or the control group. However, when the whole sample was examined, the scores of all motor skills were correlated with GPA, except for the PPT BH subtest. The strongest correlation was found between GPA and the FMHW subtest of DCDQ'07. Table 3 presents correlation analysis results.

Factors Influencing DCDQ'07 Scores

A backward stepwise linear regression was used to identify possible predictors of DCDQ'07 total score from the following candidate variables: age, gender, WISC-R total score, SNAP-IV total score, and having SLD diagnosis. At each step, variables were chosen according to their contribution to the model's R^2, and a p-value threshold of 0.1 was used to set a limit on the total number of variables included in the final model. The first step, in which all variables were included, explained 45.4% of the total variance F(5, 78)=12,994, p<0.001, and only the SNAP-IV total score (p<0.001, beta=-0.484) made a statistically significant contribution to the model. In the second step, the age variable was removed from the model. This second model explained 45.1% of the total variance, F(4, 79)=16,197, p<0.001. R^2 change was -0.004, and only the SNAP-IV total score (p<0.001, beta=-0.475) continued to contribute significantly to the model. In

Table 3: Correlation analysis for DCDQ'07, PPT subscale scores, and GPA

	Academic achievement (GPA)					
	SLD group (n=57)		Control group (n=30)		All sample (n=87)	
	r	p	r	p	r	p
PPT						
DH	0.032[a]	0.814	0.255[b]	0.182	0.209[b]	**0.055**
non-DH	0.458[a]	0.101	0.318[b]	0.092	0.297[b]	**0.006**
BH	0.123[a]	0.367	0.295[b]	0.120	0.035[b]	0.748
Ass	0.072[b]	0.596	0.204[a]	0.288	0.319[a]	**0.003**
DCDQ'07						
CDM	0.164[a]	0.226	0.926[a]	0.018	0.376[a]	**<0.001**
FMHW	0.153[a]	0.261	0.127[b]	0.511	0.618[a]	**<0.001**
GC	0.111[a]	0.414	0.049[a]	0.800	0.324[b]	**0.003**
Total score	0.171[a]	0.207	0.159[a]	0.409	0.456[a]	**<0.001**

Bold values represent p<0.05, r: Correlation coefficient. GPA: Grade point average; PPT: Purdue Pegboard Test; DH: Dominant hand; non-DH: Nondominant hand; BH: Both hands; Ass: Assembly; DCDQ'07: Developmental Coordination Disorder Questionnaire; CDM: Control during movement; FMHW: Fine motor and handwriting; GC: General coordination; a: Pearson's correlation coefficient; b: Spearman's rho correlation coefficient.

Table 4: Overview of the regression model indicating the variables influencing the DCDQ'07 scores in the sample

	B	SE	Beta	t	Sig.	95% CI		VIF
						Lower bound	Upper bound	
Constant	55.892	5.866		9.528	**<0.001**	44.221	67.564	
SLD diagnosis	7.645	2.912	0.269	2.626	**0.010**	1.852	13.439	1.503
SNAP-IV total score	-0.558	0.123	-0.464	-4.525	**<0.001**	-0.803	-0.313	1.503

R^2=0.433, F(2, 81)=30.903, p<0.001; SLD: Specific learning disorders; SNAP-IV: Swanson, Nolan and Pelham Scale-IV; SE: Standard error; CI: Confidence interval; VIF: Variance inflation factor; p<0.05 statistically significant (bold values).

the third step, the WISC-R total score was excluded from the model, which explained 44.2% of the variance F(3, 80)=21,096, p<0.001. R^2 change was -0.009. In the third model, having an SLD diagnosis (p=0.015, beta=0.256) contributed significantly to the model, in addition to the SNAP-IV total score (p<0.001, beta=-0.484). In the fourth step, the gender was removed from the model, and the total variance explained by the final model as a whole was 43.3%, and R^2 change was -0.009. Starting with five variables that might be good predictors of DCDQ'07 total score, a backward deletion regression model was able to reduce them to 2, which were: having SLD diagnosis and SNAP-IV total score as risk factors. The final model is presented in Table 4.

DISCUSSION

The results of our study showed that the rate of "suspect of DCD" among children with SLD was as high as 70%. On the other hand, ADHD comorbidity was quite common in children with SLD, and 4 out of 5 children with SLD in our study were diagnosed with comorbid ADHD. For this reason, ADHD symptom severity was considered in our analyses. Both the total and all subtest scores of the DCDQ'07, which measures motor coordination skills in daily life, were worse in the SLD group, but after the ADHD effect was controlled, the difference remained only in the FMHW and total score areas. In the PPT, in which manual skills were evaluated, there was a statistical difference between the two groups in the Ass and non-DH subtests. Even after controlling the effect of ADHD symptoms, children with SLD still had worse motor performance in these two areas than the controls. Contrary to our hypothesis, the correlation between motor skills and academic achievement was not observed in the SLD group; however, GPA correlated with almost all motor skill scores when the whole sample was examined, regardless of the group effect. In addition, consistent with our hypothesis, SLD diagnosis and ADHD symptom severity were predictive of motor problems according to our regression analysis.

In our study, almost all children with SLD had at least one comorbid psychiatric disorder, especially with ADHD. Studies indicate ADHD comorbidity in the range of 51%–82% of children with dyslexia (40,41). In addition, our findings confirmed studies showing that other psychiatric disorders that affect emotions and behavioral control, such as anxiety and depression, commonly accompany SLD (40). Because comorbid disorders can further deteriorate learning ability and psychosocial well-being, their identification and treatment are critical in SLD children.

When assessing manual dexterity, tasks with increased complexity proved to be a major challenge for children with SLD. While performance with the DH involves previously learned, simpler motor movements, performance with the non-DH is assumed to involve a nonroutine and demanding task (42). Small objects are manipulated with quick, dexterous, and controlled movements in the Ass subtest. Leslie et al.'s (43) study comparing the PPT scores of participants with dyslexia with those of controls found that the most significant difference between the two groups was in the performance of the non-DH. They explained this finding as indicating impaired transfer to the nondominant hemisphere (interhemispheric transfer) because non-DH performance is triggered in the dominant hemisphere, while the dominant hemisphere (left) is responsible for fine motor control. In another study investigating the motor skills of children with dyslexia, motor impairments were found more frequently in the non-DH than in the DH (6). Recent neuroimaging studies have shown that movement complexity affects cognitive activity in the prefrontal cortex, and the Ass subtest is the most sensitive subtest to changes in the left prefrontal cortex activity. Therefore, the authors suggested that PPT is not only a measurement tool for assessing fine motor skills, but is also closely related to planning and working memory (44). Moreover, in a sample of healthy subjects, Strenge et al. (42) concluded that the non-DH and Ass subtests were associated with attentional functions. Our results, controlling for the effect of ADHD traits, showed that children with SLD performed worse on the non-DH and Ass subtests than the control group, similar to the results of Leslie et al. (43). This suggests that SLD has a disruptive effect on manual dexterity that is independent of the effect of ADHD.

The results of our study support previous studies demonstrating the prevalence of SLD and DCD comorbidity (6,45). More than two-thirds of children with SLD in our sample had suspected DCD according to the DCDQ'07. Although the common coexistence of these two clinical conditions is well known, debates about the underlying biological mechanisms continue. Some researchers have suggested that motor impairments with learning disorders are associated with comorbid ADHD (46,47). On the other hand, a common neural system problem such as cerebellar dysfunction causing reading difficulties, motor deficits, and other comorbidities is thought to underlie a common neural system problem (48). When we controlled for the ADHD effect in our study, the difference in DCDQ'07 total scores remained, but only the difference in the FMHW subtest remained among the subtests. Our results support the view that ADHD symptoms contribute to gross motor and balance difficulties in children with SLD (6). Moreover, confirming previous studies (8,49), our study included a group with SLD without motor deficits. This phenomenon can be interpreted as a motor impairment occurring in a specific subgroup in SLD. We also observed some differences between groups in manual dexterity and handwriting, independent of ADHD symptoms. These results are contradictory to the findings of White et al. (50) who showed that children with reading difficulties had similar fine motor skills compared with controls, but had problems with balance. One reason for this could be the excess of children with dysgraphia in our study group. It has been suggested that dysgraphia is a form of DCD that affects handwriting movements and is more closely associated with motor system problems (49). Therefore, the high number of children with dysgraphia in our study group may have resulted in even lower scores of fine motor skills in the SLD group. A separate evaluation for SLD subgroups in future studies will help to further comprehend these associations.

One of the striking findings of our study is that parents' had low awareness of their children's motor skills. In our study, we observed that the proportion of those who answered the question about their children's motor skills in consistent with the scale results before moving on to the detailed motor skill questions of the DCDQ'07 remained quite low. This proportion was even lower in the control group. This result suggests that children without academic problems may have motor problems that their parents overlook. Impairment in motor skills is an underestimated area in both research and clinical practice. However, motor skills can impact many areas of life, from independence in self-care, such as dressing and washing, to peer acceptance in active play (19,51). Therefore, interventions are thought to be needed to increase parents', teachers,' and clinicians' awareness of motor skills, which are an important area of neurodevelopment.

While no correlation was observed between motor skills and academic achievement in the SLD group, it is surprising that almost all motor skill scores were associated with GPA in the analysis including all samples. Although the association between academic achievement and motor skills in the general population has been shown (18,52), Chaix et al. (6) suggested contradictory results in individuals with the reading disorder. It can be concluded from our results that the relationship between academic achievement and motor skills can be established independently of the diagnosis of SLD. In primary school, at least one-third of the day is spent on writing and fine motor skills, which are considered specifically related to cognitive development (18,52). Consistent with the previous studies (18,53), our findings indicated fine motor skill and handwriting mastery as the domain most strongly associated with higher academic achievement despite weak associations with various aspects of motor skills. On the other hand, the fact that no relationship was found in the analysis of the groups separately in our study may be due to the limited number of participants in the groups, and consequently, the relationships may have reached statistical significance when the whole sample is included. Nevertheless, our findings support the relationship between motor skills and academic achievement. It can be deduced that adding a component addressing motor skills development may be beneficial to improving academic learning interventions in childhood.

Our regression analysis results confirm that ADHD and SLD are important predictive factors of DCD. This result is consistent with studies showing a closer relationship between motor impairments and ADHD accompanying learning disorders (6). Considering that these two neurodevelopmental disorders have high comorbidity, the importance of assessing motor skills in these children becomes even more apparent. Using short scales as part of the clinical assessment, identifying and observing some essential motor progress as indicators can provide quick and practical solutions for motor skills assessment.

Our study has some limitations. First, our study is a cross-sectional design with a small sample size. Second, in the control group, the rate of the suspect of DCD was 23%. This rate in the control group was higher than in previous studies (45), which may be one reason why there was no statistically significant difference in the other subtests of PPT and DCDQ'07. In addition, no observations were made on DCD, but a parent-based reporting scale was used. Potential bias due to the lack of any randomization in sample selection, the low number of the control group, the lack of control group with ADHD, and the inability to test the hypotheses adequately due to high ADHD comorbidity were important limitations. Nevertheless, these results contribute to our understanding of motor skill problems in children with SLD.

CONCLUSION

Our study indicates that a significant proportion of children with SLD suffer from motor problems and that the common comorbidity ADHD plays a significant role in these problems. This suggests that additional motor skills training in intervention programs for children with SLD may contribute to their academic, social, and emotional development. Although it has been known that motor deficits accompany neurodevelopmental disorders for many years, there remains a need for a more comprehensive understanding and awareness of motor skills problems in these children.

Contribution Categories		**Author Initials**
Category 1	Concept/Design	A.B.E., O.T.P.F.
	Data acquisition	E.F., O.T.P.F.
	Data analysis/Interpretation	A.B.E., O.T.P.F.
Category 2	Drafting manuscript	O.T.P.F., E.F.
	Critical revision of manuscript	A.B.E.
Category 3	Final approval and accountability	O.T.P.F., A.B.E., E.F.

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