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The Relationship between Motor Coordination and Social Behavior Problems in Adolescents with Attention-Deficit/ Hyperactivity Disorder

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ÖZET:

Dikkat Eksikliği Hiperaktivite Bozukluğu tanısı konulan ergenlerde motor koordinasyon ve sosyal davranış sorunlarının ilişkisi

Amaç: Dikkat eksikliği hiperaktivite bozukluğu (DEHB) en sık görülen çocukluk çağı nörogelişimsel bozukluklarından birisidir ve DEHB tanısı konulan bireylerin %30-50'sinin aynı zamanda eşlik eden motor koordinasyon sorunları olduğu bildirilmektedir. Bu çalışma DEHB tanısı konulan çocuklarda motor koordinasyon becerilerini ve motor koordinasyon sorunlarının sosyal sorunlarla ilişkisini incelemeyi amaçlamıştır.

Yöntem: Çalışmamızda vaka grubunu DEHB tanısı konulan 12-15 yaş arası 64 çocuk oluşturdu. Kontrol grubu vaka grubu ile benzer yaş ve cinsiyet aralığında bulunan 69 çocuktan meydana gelmekteydi. Çocukların değerlendirilmesinde, Çivili Tahta El Beceri Testi (ÇTEBT), Çocukluk Çağı Davranış Değerlendirme Ölçeği ve Okul Çağı Çocukları İçin Duygulanım Bozuklukları ve Şizofreni Görüşme Çizelgesi kullanıldı. Zeka düzeyi, Wechsler Çocuklar için Zeka Ölçeği kullanılarak değerlendirildi.

Bulgular: DEHB grubunda kontrol grubuna oranla daha çok sayıda çocuk motor koordinasyon sorunu yaşamaktaydı ve DEHB grubunda sosyal sorunlar motor becerilerle ilişkiliydi. Kontrol grubunda, kızların erkeklere oranla motor becerileri daha iyi olmasına rağmen, DEHB grubunda cinsiyetler arasında anlamlı bir fark bulunmadı. DEHB grubunda kontrol grubuna oranla ÇTEBT baskın el, baskın olmayan el ve bileşik oturum alt test puanlarına göre daha fazla sayıda kız çocuğunun motor koordinasyon sorunu vardı, buna rağmen her iki gruptaki erkek çocuklar arasında ÇTEBT'nin hiçbir alt testinde anlamlı bir fark saptanmadı. DEHB grubunda ÇTEBT'de sadece her iki elin kullanıldığı alt testler yaş ile ilişkiliydi.

Sonuçlar: Sonuçlarımız DEHB grubunda motor koordinasyon sorunları ile sosyal sorunlar arasında ilişkili olduğunu göstermektedir. DEHB tanısı konulan kız çocuklarındaki yetersizliklerin ve eşlik eden motor koordinasyon sorunlarının gözardı edilmemesi gerektiği düşünülmektedir.

Anahtar sözcükler: Dikkat eksikliği hiperaktivite bozukluğu, motor beceriler, sosyal sorunlar

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ABSTRACT:

The relationship between motor coordination and social behavior problems in adolescents with Attention-Deficit/ Hyperactivity Disorder

Objective: Attention-deficit/hyperactivity disorder (ADHD) is one of the most common neurodevelopmental childhood disorders and 30-50% of individuals with ADHD are reported to also have a co-morbid motor coordination problem. This study aimed to examine motor coordination skills, and the correlation between motor coordination problems and social problems in children with ADHD.

Method: In our study, the ADHD group was composed of 64 children between 12-15 years that were diagnosed with ADHD. The control group included 69 children in a similar age and sex range to the ADHD group. The Purdue Pegboard Test (PPT), the Child Behavior Checklist and the Kiddie Schedule for Affective Disorders and Schizophrenia were used in the assessment of children. IQ was assessed using the Wechsler Intelligence Scale for Children-Revised.

Results: More children in the ADHD group had motor coordination problems than in the control group and social problems were correlated with motor skills in the ADHD group. While the girls in the control group had better motor skills than the boys, there were no significant differences between genders in the ADHD group. More girls in the ADHD group had motor coordination problems than in the control group, according to the PPT dominant hand, non-dominant hand, and assembly subtest scores whereas there was no significant difference in any of the PPT subtest scores between the boys in both groups. Age was associated only with PPT bimanual subtest scores in ADHD group.

Conclusions: The present results show that there is a relationship between motor coordination problems and social problems in an ADHD group. It is also suggested that the impairment of girls with ADHD and comorbid motor coordination problems should not be underestimated.

Key words: Attention deficit hyperactivity hisorder, motor skills, social problems

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INTRODUCTION

Attention-deficit/hyperactivity disorder (ADHD) is one of the most common neurodevelopmental childhood disorders, affecting 3%-7% of school-age children (1). Deficits in complex coordination of movement, such as during dressing, feeding, riding a bicycle, and/or handwriting, may interfere with an ADHD child's daily functioning and negatively affect his/her academic performance (2). ADHD with marked impairment in the development of motor coordination is referred to as developmental coordination disorder (DCD), and 30-50% of individuals with ADHD are reported to also have a co-morbid diagnosis of DCD (3).

It remains unclear whether the association between motor coordination problems and ADHD is comparable for children of different ages. It has been hypothesized that the growth spurt that occurs during puberty, during which children tend to become clumsier, causes an increase in the severity of problems in children with poor motor coordination (4). This hypothesis was partially confirmed in a study in which children with severe motor coordination problems continued to have such problems following the pubertal growth spurt, whereas children with mild motor coordination problems did as well as those in the control group after the growth spurt (5). Another study reported that motor coordination problems were primarily observed among younger children those aged 6-9 years in the ADHD group (6).

The relationship between ADHD and gender is another contentious issue. The ADHD literature is primarily based on boys, as ADHD is more frequently observed in boys than in girls (7); however, research on girls with ADHD shows that their neuropsychological functioning and behavior are affected in a similar fashion as in boys with ADHD (8). In contrast to an earlier study, a more recent study reported better motor coordination in healthy girls than in those with ADHD, according to Purdue Pegboard Test (PPT) scores (9, 6).

Although motor skills are commonly studied in children with ADHD, the relationship between motor coordination problems and comorbid behavioral problems in ADHD remains unclear. Children with ADHD and motor dysfunction had more severe social problems than those with ADHD only, based on parent and teacher observations (10). Moreover, individuals with the combination of motor coordination problems and ADHD were more likely to have high levels of autistic traits than those with ADHD alone (11).

The aim of the present study was to examine the relationship between ADHD and motor coordination via comparison of the effects of sex and age on motor coordination in children with ADHD and healthy controls. Additionally, this study aimed to examine the relationship between motor coordination problems and social problems in children with ADHD. We addressed the following questions: (1) is the relationship between ADHD and motor coordination problems comparable for children of different ages, (2) is the relationship between ADHD and motor coordination problems similar for boys and girls, and (3) is there a relationship between the social problems and motor problems in ADHD?

The study's hypothesis was that motor coordination would be negatively affected by ADHD and associated with social problems in children with ADHD. It was also hypothesized that there would be an effect of age and sex on motor coordination in the ADHD group.

MATERIALS AND METHODS

Participants

The ADHD group was composed of 64 children aged 12-16 years that were diagnosed as ADHD, according to the Diagnostic and Statistical Manual of Mental Disorders, Fourth edition criteria (DSM-IV) (12). The ADHD group was selected from a population of children referred by their family physician to the Marmara University Medical Faculty Department of Child and Adolescent Psychiatry, Istanbul, Turkey between 2008 and 2009. Children were classified as ADHD-hyperactive/impulsive (ADHD-H/I), ADHD-combined

(ADHD-C), or ADHD-inattentive (ADHD-I) by means of the Kiddie Schedule for Affective Disorders and Schizophrenia Present and Lifetime Version (K-SADS) structured diagnostic interview.

The control group included 69 children aged 12-15 years that were attending mainstream public schools. Permission to perform the study was obtained from the Department of Education, Istanbul, as well from the principals of the schools from which the participants were selected. None of the children in the control group had a psychiatric diagnosis according to K-SADS. Motor coordination was assessed with a manual test, therefore DCD was not screened for in both groups, and autistic symptoms were evaluated using a clinical interview based on the DSM-IV criteria for autistic spectrum disorders. In both groups, children with an IQ <70 and/or with a history of psychosis, pervasive developmental disorder, or severe neurological or medical problems were excluded. Children in the ADHD group were recommended to cease psychostimulant medication one week before the time of testing. Parents or guardians provided written informed consent. The study protocol was approved by the University of Marmara, School of Medical Sciences Ethics Committee (no. 0241/2008).

Measures

Parents of the participants completed a detailed sociodemographic form and the Child Behavior Checklist for Ages 4-18 Years (CBCL) (13), which was used to assess affective and behavioral problems. ADHD was diagnosed based on the K-SADS Turkish version (14). IQ was assessed using the Wechsler Intelligence Scale for Children-Revised (WISC-R) (15), which was adapted for use with Turkish children.

Motor coordination was measured using the PPT, which includes the following 4 subtests: dominant hand (DH), non-dominant hand (nDH), both hands (BH) and assembly (Ass). The test requires that a child inserts pegs into the holes of a board as fast as possible, completing 1 row before starting the next. The test was performed once with each hand, always starting with the dominant hand. Each child was allowed 30 s for the DH, nDH, and BH subtests, and 1 min for the Ass subtest. The final score for each subtest was calculated as the total number of pegs inserted. This test measures how quickly and accurately a child insert the pegs into the holes, so lower scores indicate poorer performance. The PPT measures fine motor coordination, which is defined as the ability to perform rapid, skillful controlled movement of small objects in which the fingers are primarily involved. Whereas the DH and nDH subtests are expected to determine the isolated unimanual movement of limbs, the BH and Ass subtests are expected to indicate the level of mutual assimilation of both hands. It should be noted that both hands must perform independently of each other during the Ass subtest, whereas they must perform in a coordinated manner during the BH subtest. The test was described and validated by Tiffin (16), and more recently Gardner and Broman (17) published normative data for children and adolescents aged 5-15 years. The Grooved Pegboard Test, a kind of PPT, has previously been used in a group of children with ADHD for the assessment of motor speed and eye-hand coordination (6). To determine the dominant hand, each of the participants was asked to write their name. The participants were informed about the details of the test before the procedure. Before each test, the required test was demonstrated, the directions were given in the local language, and the participants were allowed to practice the test 3 times. The testing procedure for each child lasted about 10 min and was conducted by a child/adolescent psychiatrist.

Statistical Analysis

All statistical analyses were performed using the SPSS v.15.0. Various mean scores were compared using Student's t test, correlations were analyzed using Pearson's correlation coefficients, and differences in frequencies between groups were analyzed using the χ^2 test. As the ADHD group had significantly lower IQ scores than the control group, IQ was controlled using covariant analysis (ANCOVA) for group statistics. P values < 0.05 were considered statistically significant.

RESULTS

There were not any significant differences in terms of mean age or sex between the ADHD and control groups. Mean verbal, performance, and total IQ scores were lower in the ADHD group (Table 1). In the ADHD group, 17 (26.6%) children were diagnosed with ADHD-I, three (4.7%) children were diagnosed with ADHD-H/I, and 44 (68.8%) children were diagnosed with ADHD-C. Children in the ADHD group had comorbid diagnoses of oppositional defiant disorder (21.9%), conduct disorder (7.8%), tic disorders (17.2%), developmental learning disorders (4.7%), disorders of communication (4.7%), depressive disorders (4.7%), anxiety disorders (17.2%) and encopresis (1.6%). Of the children in the ADHD group, 54.7% (n=35) had at least one comorbid diagnosis.

Analysis I: Group effects

Significantly more of those in the ADHD group had motor coordination problems than controls according to the PPT DH (t = –2.958, p= 0.004), nDH (t= –0.565, p= 0.001), BH (t = –2.179, p= 0.031), and Ass (t= –4.057, p<0.001) subtests. After controlling IQ scores, the differences between groups were limited to DH ($F_{1.130}$= 4.192, p= 0.043) and nDH ($F_{1.130}$= 4.697, p= 0.032) subtest scores, whereas there were no statistically significant differences in BH ($F_{1.130}$= 0.257, p= 0.613) or Ass ($F_{1.130}$= 3.861, p= 0.052) subtest scores.

Analysis II: Social problem effects

Those in the ADHD group had higher mean CBCL withdrawn behavior ($F_{1.130}$ = 13.790, p ? 0.001), anxious/depressed behavior ($F_{1.130}$= 9.430, p= 0.003), somatic complaints ($F_{1.130}$= 4.945, p= 0.028), social problems ($F_{1.130}$=34.642, p ? 0.001), thought problems ($F_{1.130}$= 22.675, p ? 0.001), attention problems ($F_{1.130}$= 160.653, p ? 0.001), delinquent behavior ($F_{1.130}$= 45.815, p ? 0.001), aggressive problems ($F_{1.130}$= 70.461, p ? 0.001), externalizing problems ($F_{1.130}$, p ? 0.001), internalizing problems ($F_{1.130}$= 21.125, p ? 0.001), and mixed problems ($F_{1.130}$= 94.014, p ? 0.001)

Table 1: Group characteristics according to age, sex, and intelligence level

Demographic characteristics	ADHD group (n= 64) Mean (SD)	Control group (n= 69) Mean (SD)	Statistical analyses Test statistic, p value
Age (years)	13.2 (1.3)	13.0 (1,3)	t = –1.2, p = 0.689
Verbal IQ	90.1 (14.8)	110.3 (13.0)	t = –8.6, p < 0.001
Performance IQ	98.3 (14.2)	114.8 (14.8)	t = –6.6, p < 0.001
Full scale IQ	94.1 (13.3)	113.2 (13.3)	t = –8.3, p < 0.001
	n (%)	n (%)	
Male	32 (50)	34(49.3)	χ^2 = 0.007, p = 0.933

SD: Standard deviation; ADHD:Attention Deficit/Hyperactivity Disorder; IQ: Intelligence Level.
Student's t test, χ^2 test

Table 2: Pearson's correlation coefficients: The correlation between CBCL subscale scores and PPT subtest scores in the ADHD group.

CBCL subscales	PPT scores			
	DH	nDH	BH	Ass
Withdrawn behavior	0.028	0.075	0.049	–0.103
Somatic complaints	–0.189	–0.226	–0.063	–0.306*
Anxious/depressed behavior	–0.085	–0.064	–0.033	–0.187
Social problems	–0.345**	–0.468 **	–0.311*	–0.335**
Thought problems	–0.068	–0.197	–0.095	–0.220
Attention problems	0.024	–0.131	–0.124	–0.147
Delinquent behavior	–0.028	–0.080	0.051	–0.090
Aggressive behavior	–0.093	–0.107	–0.111	–0.193

*p < 0.05 , **p < 0.01

Table 3: Mean number of pegs inserted, according to sex and group (ANCOVA includes IQ as covariate).

PPT	ADHD Mean (girls × boys) Statistical analyses	Control Mean (girls × boys) Statistical analyses	Girls Mean (ADHD group × Control group) Statistical analyses	Boys Mean (ADHD group × Control group) Statistical analyses
DH	15.360 × 15.203 $F_{1.61}$ = 0.099, p = 0.754	17.145 × 15.557 $F_{1.66}$ = 9.586, p = 0.003*	15.181 × 17.349 $F_{1.64}$ = 8.934, p = 0.004*	15.329 × 15.396 $F_{1.63}$ = 0.015, p = 0.903
nDH	13.497 × 13.347 $F_{1.61}$ = 0.083, p = 0.775	15.150 × 14.051 $F_{1.66}$ = 6.821, p = 0.011*	13.362 × 15.269 $F_{1.64}$ = 10.020, p = 0.002*	13.592 × 13.825 $F_{1.63}$ = 0.174, p = 0.678
BH	21.234 × 21.985 $F_{1.61}$ = 0.654, p = 0.422	23.574 × 22.262 $F_{1.66}$ = 2.857, p = 0.096	21.443 × 23.395 $F_{1.64}$ = 2.546, p = 0.115	22.512 × 21.753 $F_{1.63}$ = 0.684, p = 0.411
Ass	32.404 × 32.471 $F_{1.61}$ = 0.002, p = 0.967	38.788 × 35.365 $F_{1.66}$ = 4.686, p = 0.034*	33.050 × 38.183 $F_{1.64}$ = 5.047, p = 0.028*	33.492 × 34.419 $F_{1.63}$ = 0.280, p = 0.599

*p<0.05

PPT; Purdue Pegboard Test, DH; Dominant Hand, nDH; nonDominant Hand, BH; Both Hands, Ass; Assembly.

subscale scores. Of note, comparison of the PPT subtest scores and CBCL subscale scores indicated that only social problems were significantly correlated (Table 2).

Analysis III: Gender effects

Gender was related to motor performance. More girls in the ADHD group had motor coordination problems than in the control group, according to PPT DH, nDH, and Ass subtest scores ($F_{1.64}$= 8.934, p= 0.004; $F_{1.64}$= 10.020, p= 0.002; $F_{1.64}$= 5.047, p= 0.028; respectively) whereas there was not a significant difference in any of the PPT subtest scores between the boys in both groups (DH: $F_{1.63}$= 0.015, p= 0.903; nDH: $F_{1.63}$= 0.174, p= 0.678; BH: $F_{1.63}$= 0.684, p= 0.411; Ass: $F_{1.63}$= 0.280, p= 0.599). In addition, according to the PPT, in the control group girls had better motor skills than boys, whereas in the ADHD group there was not a significant difference between genders (Table 3).

Analysis IV: Age effects

In the ADHD group there was a positive mild to moderate statistically significant correlation between age, and PPT BH subtest score (r= 0.346, p= 0.005) and Ass subtest score (r= 0.384, p= 0.002), whereas there was not a correlation between age, and PPT DH subtest score (r= 0.237, p= 0.059) or nDH subtest score (r= 0.166, p= 0.191).

DISCUSSION

The present study aimed to expand our knowledge about the relationship between motor coordination problems and behavioral problems in children with ADHD. The present finding that there was a relationship between ADHD and low-level motor performance is in agreement with previous reports (6,18). The present study examined and compared motor coordination in children with and without ADHD. More children in the ADHD group had motor coordination problems than in the control group; the difference was significant based on all PPT subtests. There was a significant difference in IQ scores between the 2 groups, but after controlling IQ scores the difference between the groups was limited to PPT DH and nDH subtest scores. In terms of the effect of IQ on motor problems, the observed low-level motor performance in the ADHD group during the unimanual PPT subtests might have been be due to attention deficits or hyperactivity/impulsivity, whereas during the bimanual PPT subtests low-level performance might have been due to delayed cognitive development. Children with ADHD have difficulty in performing motor activities that require

inhibiting and sequencing the motor action, and the observed deficiency during the PPT unimanual subtests might have been due to difficulty attending to a given task, following the instructions, terminating the task, organizing actions, and difficulty related to spatial tasks (19). Additionally, children with ADHD were reported to have delayed cortical maturation, particularly in some prefrontal regions responsible for such specific cognitive instructions as motor planning and attention skills (20).These present results are in agreement with the DSM-IV description of the difficulties observed in children with ADHD which indicates symptoms of ADHD are related with motor coordination (12).

The relationship between motor skills and social functioning in ADHD has been previously studied (10). In the present study, motor coordination problems were negatively correlated with the CBCL social problems subscale score. High CBCL social problem subscale scores indicate poor social skills, meaning that social skills are directly correlated with motor performance in ADHD. Consistent with predictions, children with ADHD are rejected by their peers socially, and they have fewer dyadic friends in comparison to their classmates (21), but the relationship between motor coordination problems and social functioning in ADHD remains uncertain. The severity of social problems in children with DCD was found to be greater than that of the children without DCD according to parental reports (22), whereas no relationship between clumsiness and the CBCL social problem scale was observed in children aged 8-17 years (23). More children with ADHD and motor problems had social problems than those with ADHD only (10, 11). It was also reported that deficits in social reciprocity were comorbid problems in children with DAMP (deficits in attention, motor control and perception) (24). The combination of hyperactivity, impulsivity, and inattention is likely to negatively affect the fine-tuning of social behavior and motor skills (25). Sergeant and colleagues (3) have described possible mechanisms of the relationship between ADHD and motor coordination problems in terms of a theoretical cognitive-energetic model that assumes specific underlying cognitive processes lead to ADHD symptoms, motor coordination problems, or both. They suggest possible roles of encoding deficits, working memory deficits, and executive dysfunction. Executive function deficits have been found in ADHD, as well as autism which mainly represent social skill problems and they may also underlie some aspects of motor coordination difficulties (26,27,28). These implications on executive function deficits are consistent with our findings which suggest a cognitive network between specific neural pathways. As such, it is appropriate to screen for motor coordination problems and other disorders that contribute to psychiatric problems and psychosocial maladjustment in children with ADHD so that therapy and special education can be offered in a time-effective manner. However, these explanations cannot reveal the relationship between motor skills and social problems in ADHD directly. It has been reported that, children with ADHD and motor problems were more likely to have severe ADHD-combined type and social/behavioral problems than children with ADHD only (10). Therefore, it is still unknown whether the social problems are related to the severity of ADHD symptoms or motor problems directly.

The second question was whether the relationship between ADHD and motor coordination problems is comparable for children of different ages. The effect of age on motor skills, as reported by Meyer and Sagvolden (6) indicates that coordination problems are less common among older children (10-13 years) than younger children (6-9 years). Fliers et al. (2008) reported similar findings that controls performed better than children with ADHD at all ages, and motor coordination of children with ADHD improved with age. In the present study there was not a correlation between age and the level of motor coordination based on the PPT unimanual DH and nDH subtests, whereas motor coordination improved gradually with age according to the PPT bimanual BH and Ass subtests. Unimanual subtasks are easily executed in isolation, but interlimb coordination requires additional computational resources to integrate the limbs' movements into a common spatiotemporal pattern. Even if symmetrical bimanual actions are highly

compatible and are executed with great ease, non-symmetrical actions are considered to be more complex due to their lower degree of compatibility that requires some additional effort to prevent the emergence of interlimb interference (20). In typically developed children and in children with ADHD the transcallosal inhibition considered necessary for suppressing motor overflow, is found to improve with age; however, there is a delay in children with ADHD compared to typically developed children (29,30). The present results indicate that complex bimanual movements improve with age in children with ADHD, whereas simple unimanual movements do not, and this discrepancy between unimanual and bimanual subtest scores may be due to improvement of interhemispheric integration, or cortical development with age.

The present study also examined the effects of gender on motor coordination. According to the PPT, in the control group girls had better motor skills than boys, whereas in the ADHD group there were no significant differences between genders. A recent study reported that the frequency of motor coordination problems was higher in boys than girls; fewer girls in the control group had motor coordination problems than normal boys, whereas there was not a significant difference between genders in the ADHD group, which is in agreement with the present findings (18). Furthermore, significantly more girls with ADHD had motor coordination problems than the girls in the control group, although the frequency of motor coordination problems among the boys was similar in both groups. This finding supports Biederman et al.'s (31) finding that although ADHD occurs less frequent in girls, the symptoms appear to be more severe than in boys and implies that the impairment of girls with ADHD and comorbid motor problems should not be underestimated.

In a cross-sectional study females had earlier peak cerebellar volume than males (32). Findings from an anatomical MRI study show that systems underlying motor development reach maximum size one year earlier in girls than in boys (33). Furthermore, both girls and boys show an increase in white matter and corpus callosum volume from 6-17 years of age; however, girls show these developmental changes gradually over this age range, while boys show a dramatic increase over a shorter time period in adolescence (34). In the present study girls in the control group had higher PPT scores than boys, which may have been due to the sex difference in maturation. However, the discrepancy between genders disappears in the ADHD group. In contrast to the typically developing children, cerebellar dysfunction and delay in regional cortical maturation has been observed in children with ADHD (20,35) and the disappearance of sexual dimorphism in the ADHD group can be explained by the privileged effect of ADHD on cerebellar and cortical maturation.

Strengths and Limitations

The present results should be interpreted in the context of the study's strengths and limitations. The study's strength is the methods used to evaluate motor coordination and diagnose ADHD. Motor coordination was assessed directly using an objective motor performance test administered to each child rather than using parent or teacher rating scales, and ADHD was diagnosed based on a semi-structured interview. In addition, as the assessment of motor functioning and diagnosis of ADHD were performed by an experienced and unbiased clinician, the risk of error was considered to be low. However, the method that was used to evaluate motor performance was limited to only fine motor skills. Motor skill assessments including gross motor performance and kinesthesis may improve the results of the study. Furthermore, it is a general finding that children with ADHD have somewhat lower intelligence than control children (36). In our study, IQ was estimated using the WISC-R and was controlled using an ANCOVA, because the ADHD group had lower IQ scores than the control group. This procedure yielded a significant finding concerning the effect of IQ on motor coordination, and as such any statistical bias due to the ADHD group was negated.

Further research is needed in a number of areas.

First, a severe limitation of this study concerns the method by which social problems were evaluated. In our study, behavioral and social problems were examined with a questionnaire answered by parents. Clinical assessments and comprehensive observations including multiple areas of daily life are needed to evaluate the overall social functioning of the child. Second, our results didn't consider the effects of comorbid problems on motor skills and social functioning. Behavioral problems such as oppositional defiant disorder or anxiety disorders may impair the motor and social functioning of the child, which were found to be directly related with each other in our study.

Hence a systematic study on the effect of comorbid problems on social interactions and motor skills is strongly needed. Third, in our study, the relationship between motor coordination and social functioning was analysed using Pearson's correlation coefficients, a basic statistical method. Since motor problems and social dysfunctioning often exist together in children with ADHD and the incidence of both problems is relatively high in ADHD, a coincidental relationship might have been revealed in our results. Therefore, further statistical analyses should be used to determine the predictive factors of motor coordination in ADHD. Fourth, the age range of the subjects, who participated in the current study, was 12 to16 years. The limited age range in the ADHD group may restrain the evaluation of developmental issues regarding motor coordination. Last but not least, the subgroup effect on motor skills group could not be examined due to the small number of children in the ADHD group. It has been reported that the impairment in fine motor skills was most severe for the subgroup with symptoms of ADHD-C and less severe for the subgroups with symptoms of ADHD-I and ADHD-H/I (6). Replication of the current findings with a large number of subjects is recommended for identifying the effects of subgroups on motor skills in ADHD.

CONCLUSION

The findings of the present study highlight the importance of the relationship between motor coordination problems and social problems in children with ADHD. Although motor coordination in ADHD is a popular research topic, few studies have examined the association between motor coordination problems and social problems (3,6,18). It has been reported that children with ADHD and motor problems have more severe social problems than children with ADHD only, and that motor performance in children with ADHD improves significantly with social skills training (10,37). As such, we think that early diagnosis of comorbidities in children with ADHD and an understanding of their associations will improve ADHD treatment outcomes. In addition, further studies focusing on the effects of drug treatments on motor performance in children with ADHD would expand our knowledge and make a contribution to the results of the present study.

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