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Original Article

Equine-Assisted Activities and Therapy for Treating Children with Attention-Deficit/Hyperactivity Disorder

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Abstract

Objective: To investigate clinical effects of equine-assisted activities and therapy (EAA/T) for treating attention-deficit/hyperactivity disorder (ADHD) in children age 6–13 years.
Methods: This 12-week, prospective, open-label trial included 24 sessions of EAA/T. Twenty participants (19 boys and 1 girl) completed 12 weeks of EAA/T. Various clinical tests were administered at baseline and after EAA/T. Assessments included the investigator-administered ADHD-Rating Scale (ARS-I), Clinical Global Impressions (CGI)–Severity Scale, Clinical Global Impressions–Improvement Scale (CGI-I), Gordon Diagnostic System, Korea-Child Behavior Checklist (K-CBCL), Self-Esteem Scale, second edition of the Bruininks-Oseretsky test of motor proficiency (BOT-2), and quantitative electroencephalography. The primary efficacy measure was the response rate.
Results: The response rate was 90% based on a 30% or greater decline in the ARS-I score or 85% based on CGI-I scores of 1 or 2. The mean ± standard deviation ARS-I score decreased from 33.65 ± 6.42 at baseline to 16.80 ± 6.86 after 12 weeks of EAA/T ($p < 0.001$, paired t-test). EAA/T also resulted in significant improvement in the social problems subscale of the K-CBCL and in the manual dexterity, bilateral coordination, and total motor composite subscales of the BOT-2. The theta/beta ratio on electroencephalography was decreased significantly at the Pz electrode after 12 weeks of EAA/T.
Conclusion: This is the first study demonstrating that EAA/T is effective for improving core ADHD symptoms. On the basis of these results, EAA/T could be a viable treatment strategy as a part of a multimodal therapy for children with ADHD.

Introduction

Attention deficit/hyperactivity disorder (ADHD) is considered to be the most prevalent neurodevelopmental disorder,[1] with a prevalence of 3%–7% in school-aged children.[2] The typical characteristics of this disorder include age-inappropriate levels of inattention and/or hyperactivity and impulsivity, creating substantial impairment in social relationships and in school and home environments.[3] These impairments can continue into adulthood.[4] In addition, many children with ADHD exhibit poor balance and coordination[5] and have problems with rhythm.[6] These motor function problems are associated with low self-esteem and anxiety.[7]

The efficacy of medications for treating ADHD is well established.[8] However, some patients treated with medication do not improve adequately or cannot tolerate the side effects.[9,10] Others taking the medications report uncomfortable common side effects on sleep, appetite, or weight gain.[11] Although these medications improve core ADHD symptoms, there is less improvement in peer relationship problems or social problems.[12] Therefore, non-pharmacologic options to treat ADHD are needed. Psychosocial treatments include cognitive training, neurofeedback, behavioral treatment, and physical exercise.[13–15]

Among the psychosocial treatments, physical exercise promotes calmness in children with ADHD[16] and improves attention.[17] Motion stimulation also improves ADHD symptoms.[18]

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In particular, animal-assisted activities help children improve social thinking and social skills. Animals can facilitate a trusting alliance between the therapist and child and relieve tension and anxiety while helping the child learn social skills. In addition, interacting with animals is entertaining and fun. Equine-assisted activities and therapy (EAA/T) use horses as a therapeutic modality. During EAA/T, patients exercise and experience motion stimulation. The horse is a large, powerful animal that commands respect. Building a relationship with a horse promotes confidence, relationship skills, and problem-solving skills. EAA/T strengthens motor planning, sequencing, and timing, which may have a role improving the capacity to attend.[19]

Some studies have evaluated EAA/T in the psychiatric treatment field. Bizub et al. reported that EAA/T has therapeutic effects that augment a sense of self-efficacy and self-esteem in patients with psychiatric disabilities.[20] In another study, Tyler suggested that depressed, stressed, and angry patients experience a positive effect from the physiologic reactions to the rhythmic movement of a horse.[21]

However, few studies have assessed EAA/T in children with ADHD. Cuypers et al. applied EAA/T to children with ADHD and reported that EAA/T had a positive effect on these children in several domains of social role behavior, quality of life, and motor performance.[22]

No study has evaluated the effects of EAA/T on core symptoms of ADHD, including inattention, hyperactivity, and impulsivity. This study evaluated the effectiveness of EAA/T for treating ADHD in children age 6–13 years. The study hypothesis was that EAA/T would improve core ADHD symptoms. The primary objective of this study was to estimate the response rate of EAA/T. Another hypothesis was that EAA/T would improve social and behavioral competence and motor performance in children with ADHD.

Materials and Methods

Patients

This study was conducted between January 2013 and September 2013. A total of 22 patients (21 boys and 1 girl) were enrolled. The patients (age 6–13 years old) had visited the Child and Adolescent Psychiatry Service Unit at Samsung Medical Center, Seoul, Korea. They received a diagnosis of ADHD according to the American Psychiatric Association's *Diagnostic and Statistical Manual of Mental Disorders, 4th edition, Text Revision* (*DSM-IV-TR*).[23] The Korean Kiddie-Schedule for Affective Disorders and Schizophrenia-Present and Lifetime Version[24] were administered by two psychiatrists trained in the use of this interview in order to confirm ADHD and to identify any comorbidities. The presence of developmental coordination disorder (DCD) was also evaluated according to *DSM-IV-TR* criteria.

Exclusion criteria were (1) a learning disorder or an IQ measured by the Korean Wechsler Intelligence Scale for Children-IV less than 70; (2) significant medical condition, schizophrenia or other psychotic disorder, bipolar disorder, a history of alcohol or drug dependence, neurologic disorders, epilepsy, and organic mental disorders; (3) a major depressive disorder that required pharmacotherapy; (4) significant suicidal ideation; (5) Tourette disorder or obsessive-compulsive disorder that required pharmacotherapy; and (6) use of methylphenidate or atomoxetine within 90 days of baseline.

Twenty patients (19 boys and 1 girl) completed 12 weeks of EAA/T. All patients received EAA/T, and there was no placebo or control group. One patient dropped out after 2 weeks of EAA/T because of aggravation of low back pain, and 1 patient dropped out after 3 weeks because of the EAA/T schedule. This study used the data of 20 patients who completed the study because the 2 who discontinued EAA/T did not complete the post-interventional measurements. The institutional review board of Samsung Medical Center approved the study. All participants and their parents provided signed informed consent and assent.

Study design

The patients received an initial comprehensive evaluation (visit 1) to determine study eligibility. The patients were given a 30-day period before visit 2. All study measures were administered during visit 2. EAA/T started within 2 weeks after visit 2 and continued for 12 weeks. After EAA/T, all study measures were readministered (visit 3) within 2 weeks. Methylphenidate or atomoxetine was not permitted during EAA/T in order to reduce the effect of confounding factors.

EAA/T program

The EAA/T program was based on a psycho-exercise program to improve attention and inhibit impulsivity. It consisted of unmounted activities and hippotherapy sessions twice per week for 12 weeks (total of 24 sessions). Unmounted activities included putting a halter and saddle on a horse, leading the horse from stables to the riding arena, and grooming and feeding a horse. The first 3 weeks were considered a period of adaptation, which focused on developing relationships with the therapists and horses. Twenty minutes of unmounted activities was assigned, which occurred 10 minutes before and after 40 minutes of therapy on a horse during the adaptation period. Weeks 4–9 were considered the learning period, which focused on developing skills, exercising, improving attention, and inhibiting impulsivity. The preparation time for the unmounted activities was shortened as patients improved their skills, which increased their time for on-horse activities and therapy. The last 3 weeks (weeks 10–12) were a period to enhance skills, and the patients focused on enhancing their riding skills and increasing their independence on a horse. Each patient rode the same horse throughout the 12 weeks.

Assessments

The investigator-administered ADHD-Rating Scale (ARS-I), the Clinical Global Impressions Scale (CGI), and the Gordon Diagnostic System (GDS) to measure ADHD symptom improvement. The Korea-Child Behavior Checklist (K-CBCL) and Self-Esteem Scale (SES) were used to measure changes in social and behavioral competence and self-esteem, respectively. The second edition of the Bruininks-Oseretsky test of motor proficiency (BOT-2) was used to measure changes in motor function. Quantitative electroencephalography (QEEG) was used to investigate cerebral functional changes after EAA/T.

ARS-I. The ARS-I is composed of 18 items based on *DSM-IV-TR* criteria, scored from 0 (behavior never occurs or rarely) to 3 (behavior occurs very often), yielding a total score ranging from 0 to 54, with higher scores representing greater severity.[25,26]

CGI. ADHD symptom severity and improvement were also evaluated with the CGI.[27] ADHD symptom severity is rated from 1 (normal, not ill) to 7 (among the most severely ill) on the CGI-Severity scale (CGI-S). Symptom improvement was rated from 1, indicating ''very much improved,'' to 7, indicating ''very much worse'' using the CGI-Improvement scale (CGI-I).

GDS. The GDS is a popular continuous performance test. The GDS was used to compare the pre- and post-EAA/T efficiency ratio from the delay task to evaluate the effectiveness of the EAA/T. The delay task requires the child to inhibit responding to earn points, according to a ''differential reinforcement of low responding'' schedule. The patient was instructed to press a button, wait, and then press the button again. If the child waited for at least 6 seconds, a light flashed, and the point counter increased; if the child responded before the interval lapsed, the timer reset, and no points were earned. The delay task yields three primary scores: the number of responses, the number of correct responses, and the efficiency ratio (percentage of correct responses). According to the GDS manual, the efficiency ratio is the ''best single delay task indicator of the level of impulsivity demonstrated by a subject.''[28]

K-CBCL. Social and behavioral competence and ADHD symptoms were evaluated with the K-CBCL.[29,30] The K-CBCL is a parent-report questionnaire with 119 items providing data on various emotional and behavioral problems found in children. The reliability and validity of the K-CBCL are well established in Korean children and adolescents.[30] A total problem behavior score was computed by summing the scores obtained for each item. Two broad-band syndromes (internalizing problems and externalizing problems) and nine clinical scales (withdrawn, somatic complaints, anxiety/depression, social problems, thought problems, attention problems, delinquent behavior, and aggressive behavior) were produced. Externalizing behavior problems are represented by attention problems and aggressive and delinquent behavior; internalizing behavior problems are composed of withdrawal, depressed behavior, and somatic complaints. The social functioning scale includes socialization and academic functioning. The computed K-CBCL score is based on Korean normative samples, with the total problem behavior score computed by summing the scores obtained for each item. Raw scores for each clinical factor were transformed into T-scores based on published norms.

SES. The SES is self-report scale for assessing self-esteem.[26] The SES is composed of 10 closed-ended questions; the answer choices are as follows: totally agree, agree, disagree, totally disagree. Each item score ranges from 1 to 4, with high scores suggesting high self-esteem.

BOT-2. The BOT-2 was administered to measure a wide array of motor skills using a trained occupational therapist. The BOT-2 is an individually administered test using engaging, goal-directed activities and consists of 53 items and 4 motor-area composite scores (fine manual control, manual coordination, body coordination, and strength and agility). The 4 motor-area composites are each composed of 2 of 8 subtests related to aspects of motor function (fine manual control = fine motor precision and fine motor integration; manual coordination = manual dexterity and upper-limb coordination; body coordination = bilateral coordination and balance; strength and agility = running speed and strength and agility). The 53-item raw score is scaled to a standard score according to age norms. Finally, the 4 standard score sums become the total motor composite, which is an overall motor proficiency score. Occupational therapists used authenticated test kits and booklets to administer the BOT-2. Each test took 60–90 minutes, depending on the participant.

QEEG. The QEEG recording took place in a sound-attenuated and electrically shielded room. Electroencephalographic activity was recorded with eyes open during the go/no-go test for 5 minutes. The QEEG data were acquired using a Neuroscan Synamp2 amplifier (Compumedics USA, El Paso, TX) provided by 32 Ag/AgCl electrodes positioned according to the 10/20 system. The input signals were referenced to the linked ears, filtered between 0.5 and 50 Hz, and digitized at a sampling rate of 250 Hz. Impedance was kept below 5 kOhm for all electrodes.

Artifact-free 300-sec periods were recorded and analyzed. Epochs of movement-related artifacts were excluded from analyses by direct visual inspection of the raw data. Results are presented as absolute spectral power values (μV2) for individual segments of the EEG spectrum, including delta (0–4 Hz), theta (4–8 Hz), alpha (8–12 Hz), beta (12–20 Hz), and high beta (20–30 Hz). The average power spectrum of the EEG frequencies was calculated by the fast Fourier transform, a mathematical process that can be used to identify the various frequency bands (delta, theta, alpha, and beta) on QEEG.

The theta/beta ratio at the Fz, Cz, Pz, and Oz electrodes was used to evaluate the effect of the EAA/T on cerebral functional changes in children with ADHD.

Table 1. Baseline Characteristics of the Study Patients

Characteristic	*Value*
Age (y)	8.40 ± 1.85
Sex, *n* (%)	
Male	19 (95)
Female	1 (5)
ADHD subtype, *n* (%)	
Combined	14 (70)
Inattentive	6 (30)
Hyperactive-impulsive	0 (0)
Comorbidity, *n* (%)	
DCD	11 (55)
Children emotional disorder	4 (20)
Depressive disorder	1 (5)
Tic disorder	3 (15)

Age is expressed as mean ± standard deviation.
ADHD, attention-deficit/hyperactivity disorder; DCD, developmental coordination disorder.

Table 2. Baseline and Post–Equine-Assisted Activities and Therapy Scores on ADHD-Rating Scale

Variable	ARS-I score (n=20) Baseline	Post-EAA/T	Change in scores	p-Value[a]
Total score	33.60 ± 6.42	16.80 ± 6.86	16.80 ± 1.45	< 0.001
Inattention subscale score	18.95 ± 2.66	10.20 ± 3.27	8.75 ± 0.82	< 0.001
Hyperactivity-impulsivity subscale score	14.65 ± 5.63	6.60 ± 4.11	8.05 ± 1.01	< 0.001

Values are expressed as mean ± standard deviation.
[a]Paired *t*-test.
ARS-I, ADHD Rating Scale; EAA/T, equine-assisted activities and therapy.

Outcome measure

The primary efficacy measure was the response rate. Response was defined as follows: (1) a 30% reduction in the pre-treatment ARS-I score after 12 weeks of EAA/T or (2) a CGI-I score of 1 or 2 after 12 weeks of EAA/T.

Statistical analysis

Descriptive statistics are presented as mean ± standard deviation for continuous variables and as percentages and frequencies for categorical variables. Pre- and post-EAA/T scores were compared by using the paired *t*-test to assess EAA/T effectiveness. Multivariate linear regression models were used to estimate the associations between the treatment response and pre-treatment ARS-I, CGI-S, SES, and total motor composite of BOT-2 scores, as well as age. A *p*-value less than 0.05 was considered to indicate statistical significance, and statistical analysis was conducted by using SPSS software, version 17 (SPSS Inc., Chicago, IL).

Results

The data of 20 patients (19 boys and 1 girl) who completed the study were used because 2 boys who discontinued EAA/T did not complete the post-interventional measurements.

Demographic characteristics

The mean patient age was 8.40 ± 1.85 years. Fourteen (70%) patients were diagnosed with ADHD combined type, and 6 (30%) were diagnosed with ADHD inattentive type. Among the 20 patients, 13 (65%) had ADHD without any comorbidities, 1 had depression, 4 (20%) had child emotional disorder, and 3 (15%) had tic disorder. Eleven (55%) patients met the *DSM-IV* criteria for DCD (Table 1).

ADHD core symptoms: response rate

The results yielded a mean ARS-I total baseline score of 33.60 ± 6.42. The post-EAA/T score decreased to a mean of 16.80 ± 6.86. The mean ARS-I inattention score was 18.95 ± 2.66 at baseline and 10.20 ± 3.27 after EAA/T. The mean ARS-I hyperactivity score was 14.65 ± 5.63 at baseline and 6.60 ± 4.11 after EAA/T. Overall, the ARS-I total scores indicated a significant improvement compared with that of the baseline total score and the inattentive and hyperactive-impulsive subscales (all $p < 0.001$, paired *t*-test). The response rate (defined by ≥30% decline in ARS-I score from baseline) was 90% (Table 2). The mean CGI-S score was 3.95 ± 0.82 at baseline and 2.85 ± 0.74 after EAA/T (all $p < 0.001$, paired *t*-test) (Table 3). At the end of the study, 2 patients (10%) were ‘‘very much improved’’ based on a CGI-I score of 1, 15 (75%) patients had a score of 2 indicating ‘‘much improved,’’ and 3 (15%) patients were assessed as ‘‘minimally improved’’ (score of 3). Overall, 17 (85%) of the 20 patients had a CGI-I scores of 1 or 2 and were regarded as a response group. Three patients who were regarded as a non-response group had DCD. No difference was observed in the presence of DCD between the response and non-response groups ($p = 0.218$, Fisher exact test) The multivariate linear regression analyses detected no significant main effects for pre-treatment ARS-I, CGI-S, SES, BOT-2 total motor composite scores or age.

Attentional test

The mean efficiency ratio was 0.73 ± 0.13 before the intervention and 0.78 ± 0.11 at the end of the study ($p = 0.173$, paired *t*-test).

Psycho-socio-motor variables

The social problems subscale of the K-CBCL improved significantly ($p = 0.030$, paired *t*-test), but the other K-CBCL subscales did not (Table 4). The mean SES score was 27.55 ± 4.89 at baseline and 29.11 ± 4.23 at the end of the study ($p = 0.221$, paired *t*-test). The manual dexterity, bilateral coordination, and total motor composite BOT-2 subscales improved significantly ($p = 0.018$, 0.001, and 0.015, respectively, paired *t*-test) (Table 5).

Brain functional changes

The theta/beta ratio at the Fz, Cz, Pz, and Oz electrodes was investigated. After 12 weeks of EAA/T, the theta/beta ratio decreased significantly in the Pz area (5.03 to 4.21) ($p = 0.043$, paired *t*-test). Although the differences were not

Table 3. Baseline and Post–Equine-Assisted Activities and Therapy Scores on Clinical Global Impressions–Severity Scale

Variable	CGI-S score (n=20) Baseline	Post-EAA/T	Change score	p-Value[a]
CGI-S score	3.95 ± 0.82	2.85 ± 0.74	1.10 ± 0.69	< 0.001

Values are expressed as mean ± standard deviation.
[a]Paired *t*-test.
CGI-S, Clinical Global Impressions Scale-Severity.

Table 4. Baseline and Post–Equine-Assisted Activities and Therapy Scores on Korea-Child Behavior Checklist

Variable	K-CBCL score: Baseline	Post-EAA/T	Change in scores	p-Value[a]
Withdrawn	59.11 ± 6.49	59.17 ± 8.07	−0.06 ± 6.47	0.971
Somatic complaints	55.83 ± 7.52	55.55 ± 6.46	0.28 ± 5.14	0.821
Anxiety/depression	60.22 ± 9.17	59.33 ± 6.96	0.89 ± 7.58	0.625
Social problems	63.89 ± 5.38	60.55 ± 6.93	3.33 ± 6.00	0.030
Thought problems	61.28 ± 7.92	59.56 ± 9.66	1.72 ± 8.19	0.385
Attention problems	65.67 ± 12.91	64.39 ± 10.93	1.28 ± 13.18	0.686
Delinquent behavior	59.83 ± 8.50	59.05 ± 8.21	0.78 ± 8.67	0.708
Aggressive behavior	63.44 ± 10.72	61.00 ± 7.89	2.44 ± 8.18	0.222
Internalizing	59.50 ± 10.45	57.56 ± 9.06	1.94 ± 8.64	0.353
Externalizing	63.94 ± 12.02	60.50 ± 11.96	3.44 ± 9.37	0.137
Total problems	65.11 ± 10.31	61.17 ± 13.85	3.94 ± 9.83	0.107

Values are expressed as mean ± standard deviation.
[a]Paired *t*-test.
K-CBCL, Korea-Child Behavior Checklist.

significant, the theta/beta ratio decreased in the Fz (from 4.50 to 3.71), Cz (from 5.23 to 4.85), and Oz (from 2.88 to 2.52) areas after 12 weeks of EAA/T.

Discussion

The purpose of this study was to evaluate the therapeutic effect of EAA/T on children with ADHD.

Previous studies that applied EAA/T to children with ADHD investigated changes in behavior, social problems, and motor function but did not evaluate the effect of EAA/T on core ADHD symptoms, including inattention, hyperactivity, and impulsivity. This study evaluated not only the effects of EAA/T on behavioral and social problems (as well as motor function) but also the effect of EAA/T on core symptoms of ADHD.

The data suggest that EAA/T effectively improved the core ADHD symptoms in children. The ARS-I total score and the inattention and hyperactivity/impulsivity subscale scores decreased significantly. In addition, the CGI-S score decreased significantly after 12 weeks of EAA/T. The response rate was 90% based on a 30% or greater decline in the ARS-I score or 85% based on CGI-I scores of 1 or 2. The effectiveness ratio on the GDS tended to increase from 0.73 to 0.78.

Some elements of EAA/T may play a role in improving core ADHD symptoms. First, elements of physical exercise may influence the improvement in ADHD symptoms. The biological hypothesis of ADHD is based on dysfunction of catecholamines, such as dopamine, and the expert consensus is that dopamine dysregulation in the fronto-subcortical circuit is responsible for ADHD pathophysiology.[31] Studies have reported that exercise induces dopamine release.[32,33] In an animal study, Ko et al. reported that swimming exercise improves ADHD symptoms by upregulating dopamine expression and downregulating dopamine D2 receptor expression.[34] Tantillo et al. suggested that physical exercise acts as a dopaminergic adjuvant in the treatment of behavioral disturbances in patients with ADHD.[35] In this context, Kang et al. demonstrated a positive correlation between physical exercise and improved attention and cognitive symptoms.[36]

Second, the elements of motion simulation in EAA/T may influence the improvement in ADHD symptoms. The

Table 5. Baseline and Post–Equine-Assisted Activities and Therapy Scores on Bruininks-Oseretsky Test of Motor Proficiency, Second Edition

Variable	BOT-2 score: Baseline	Post-EAA/T	Change in scores	p-Value[a]
Fine motor precision	12.68 ± 4.50	12.42 ± 4.09	0.26 ± 3.09	0.715
Fine motor integration	10.68 ± 3.73	9.84 ± 3.55	0.84 ± 2.69	0.190
Manual dexterity	12.74 ± 3.72	14.58 ± 4.19	−1.84 ± 3.08	0.018
Upper-limb coordination	11.00 ± 3.82	11.84 ± 4.72	−0.84 ± 3.53	0.312
Bilateral coordination	12.74 ± 4.83	15.68 ± 4.26	−2.94 ± 3.06	0.001
Balance	8.00 ± 2.83	8.84 ± 3.15	−0.84 ± 3.20	0.267
Running speed and agility	13.16 ± 4.60	14.53 ± 5.65	−1.37 ± 5.05	0.253
Strength	13.26 ± 4.47	14.21 ± 4.72	−0.95 ± 3.52	0.256
Total motor composite	40.53 ± 6.83	43.26 ± 7.99	−2.73 ± 4.46	0.015

Values are expressed as mean ± standard deviation.
[a]Paired *t*-test.
BOT-2, Bruininks-Oseretsky test of motor proficiency, second edition.

vestibular system may be stimulated by the child's symmetric and rhythmic body movements while riding a horse. Dysfunction of the ventral tegmental-limbic dopaminergic system is also suspected in ADHD pathophysiology.[37] Vitte et al. reported that hippocampal formation is activated by vestibular stimulation,[38] providing a neuroanatomic link between vestibular stimulation and the limbic dopaminergic system. In this context, Arnold et al. reported that motion stimulation significantly improved behavioral ratings in patients with ADHD.[39] Haffner et al. also reported that body-oriented therapeutic methods can be an effective complementary or concomitant treatment for ADHD.[40]

The current study measured theta and beta wave amplitudes by QEEG and calculated the theta/beta ratio to evaluate the effect of EAA/T on cerebral function. Beta waves are associated with sustaining attention and thinking, whereas theta waves are prevalent during drowsiness or daydreaming. EEG patterns in children with ADHD show more theta wave activity and an increased theta/beta ratio compared with those in children without ADHD. Song et al. reported that the theta/beta ratio changes after administering methylphenidate to patients with ADHD.[41] The US Food and Drug Administration approved the use of the Neuropsychiatric EEG-based Assessment Aid (NEBA) system in July 2013 as a device for a complementary evaluation of ADHD. The NEBA system is based on the QEEG and includes the standardized theta/beta ratio.[42] In the current study, the theta/beta ratio was decreased significantly at the Pz electrode after 12 weeks of EAA/T. In addition, the theta/beta ratio at the Fz electrode tended to decrease. The parietal region and frontal lobes play a critical role in sustained attention or vigilance.[43,44] Tamm et al. reported that individuals with ADHD show significantly less activation in bilateral parietal lobes.[45] Thus, the current theta/beta ratio results suggest that EAA/T may positively affect cerebral function in patients with ADHD.

The results suggest that EAA/T also may have a positive effect on social problems in children with ADHD. The social problems subscale of the K-CBCL improved significantly after 12 weeks of EAA/T. Social problems include acting young, clinginess, not getting along with peers, clumsiness, and preferring to play with younger children. The SES scores tended to increase after 12 weeks of EAA/T. Riding a large, obedient animal allows patients to experience feelings of independence and capacity, which are important for acquiring self-confidence.[20] Horses have behavioral responses and social structures similar to those of humans and thereby provide a mirror for the patient to gain insight in a unique and nonthreatening environment.[46] The patients learned to control their initial emotions through rapport with the horse. Thus, EAA/T may improve not only ADHD core symptoms but also social problems.

In this study, the manual dexterity, bilateral coordination, and total motor composite subscales of the BOT-2 improved significantly after 12 weeks of EAA/T. The physiologic mechanisms that promote reciprocal responses of patients to the horse during EAA/T may play a role in improving motor function. According to previous studies, 30%–70% of children with ADHD have motor function problems,[47,48] and children who have both ADHD and motor problems have more mental health problems, such as low self-esteem and reduced efficacy in social relationships, than do children with ADHD only.[49] In the current study, 11 patients (55%) also had DCD, and the mean SES of the patients with ADHD without DCD tended to be higher than that of the patients with ADHD and DCD (28.66 versus 27.00; $p = 0.471$, independent t-test). It was assumed that the motor function improvement after 12 weeks of EAA/T may have a positive effect on self-esteem and social relationships in the children with ADHD.

The 3 patients in the nonresponse group, based on the CGI-I, all had DCD. Baseline motor function may influence the therapeutic effect of EAA/T. Thus, further study is needed.

The strength of this study was that the children participated only in EAA/T without medication. Most previous studies about exercise-related interventions for treating ADHD included patients with ADHD who had been medicated or were still being medicated.

Several limitations to the sample and methodology in this study should be considered. First, and most important, no placebo group was included. Because of the study design, unspecified factors, such as rater bias, expectation effects, and time effects could not be ruled out. However, this does not automatically compromise validity of the results.[50] Furthermore, although the mean reduction in ADHD symptoms was considerable, the results did not allow a direct comparison of EAA/T with other ADHD treatments. Further study comparing medication therapy with EAA/T is needed. Second, a small number of participants and lack of adequate representation of girls made it difficult to generalize the results to larger groups of children with ADHD. Third, the post-EAA/T assessment was done within 2 weeks, and the long-term therapeutic effects were not assessed, so maintenance of the effect was not shown. A long-term and systemic treatment with larger ADHD and control groups is needed for further understanding. Although this study applied the standardized exercise for children, each child's regimen will need to be individualized.

In conclusion, this is the first study demonstrating that EAA/T is effective for improving core ADHD symptoms. On the basis of these results, EAA/T can be considered an ADHD treatment. Moreover, combination therapy of medication and EAA/T is suggested for future studies.

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Author Disclosure Statement

No competing financial interests exist.

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