Vestibular and Balance Function in Children with Attention Deficit Disorders

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Abstract:
Objectives/Hypothesis: Attention Deficit/Hyperactivity Disorder (ADHD) designates a spectrum of disorders characterized by inattention, impulsivity and hyperactivity whose neurological foundations are largely unknown. Current research hypothesizes several mechanisms for the symptoms seen in this heterogeneous population, including vestibular dysfhnction. Past research has investigated the vestibular system in children with learning disabilities, of which ADHD is included, but no research has specifically compared vestibular function in children with and without ADHD. The objective of this study was to determine if differences in vestibular and ocular motor function, posturography and balance ability exist in children with ADHD and those without.

Study Design: Prospective

Methods: Forty children (18 with ADHI), 22 without) with an age range of 6-13 and a mean age of 9.27 participated in this study. Ocular motor and vestibular function was evaluated using computed generated eye tracking tests with infra-red oculography. Balance function was measured using the Bruininks-Oseretsky Test of Motor Proficiency. The BalanceTrak 500® system was used to perform posturography tests.

Results: Children with ADFID did significantly worse in the Bruininks-Oseretsky Test (p—O.O34). No significant differences were seen in the posturography and ocular motor testing, but children with ADHD tended to perform worse than children without. Vestibular and Balance Function in ADF{D

Coc1usions: The difference in balance function and the trends seen in the posturography and ocular motor testing are reassuring to maintain the hypothesis of deficits in the vestibular and ocular motor systems in children with ADHD. The lack of statistical significance in the vestibular and ocular motor testing is most likely due to small sample size.

Key Words: ADHD, vestibular, balance and children.

Introduction

Attention deficit/hyperactivity disorder (ADHD) is considered to be one of the most common learning disorders present in children today, affecting 4 to 9% of youth and up to 4% of adults.’ Symptoms of ADI]]) include inattention, hyperactivity, and impulsivity.2 According to DSM-IV standards, there are three types of ADHD: A predominantly inattentive subtype, and predominantly hyperactive/impulsive subtype, and a combined subtype.2 However, the neurological foundations to ADHD are largely unknown, and diagnosis is based on clinical presentation.3

Many children with ADHD are thought to have sensory motor abnormalities, including poor visual motor skills, posture, balance and spatial orientation. These sensory motor problems are widely held to be due to vestibular system deficits, specifically a sensory integration disorder, in which the brain cannot properly interpret and integrate the various modes of sensory information to one comprehensive data stream.4 However, most of the evidence provided has involved studies of children with learning disabilities, rather than specifically ADHD. Learning disorders (LD) are co-morbid in approximately one third of children with ADI{D.’ In addition, the evidence available on vestibular and/or sensory motor deficits in children with learning disabilities is contradictory, perhaps due to differences in subject selection criteria.

Shumway-Cook et a!. examined the vestibular ocular reflex (VOR) and performed posturography tests on 15 learning-disabled children who exhibited sensory motor abnonnalities. Normal VOR scores were found in 12 of 15 children, while all 15 of the LD children exhibited abnormal posturography.5 Contrarily, Levinson examined a group of 1,465 learning-disabled children who were not selected on the basis of sensory motor abnormalities. Levinson reported abnormal ENG and neurological testing results in over 95% of his subjects.6 On the basis of this study and further work, Levinson has hypothesized that an underlying cerebellar-vestibular disorder may result in symptoms of learning disability, vertigo, and motion sickness for individuals with ADHD.7

Research specifically examining the ADHD population has provided more consistent results. Rabinowitz, et a!. recently performed a study of balance function and dizziness in a population of college-aged individuals with ADHD. Significant differences from age-matched controls were found in the areas of high frequency VOR, general balance and subjective dizziness.8 Arnold et al.9 studied 30 primary school children with ADI{D. Children were placed into groups receiving either visual stimulation, vestibular stimulation or both. Behavior ratings showed significant improvement at the end of the last treatment and at follow-up one year later. The most improvement was seen with vestibular stimulation, which significantly changed behavior ratings. Effects of combined vestibular stimulation and visual stimulation were not significant. Work by Byl’° showed findings similar to those of Arnold’s. In boys with learning, reading, or inattention problems, a significant improvement in spatial perception abilities occurred within 10 days of beginning a vestibular exercise program.

Due to the contradictory evidence available, and the paucity of research on balance and vestibular function specifically in children with ADHD, this age-matched study was designed to assess vestibular function, eye movements and balance. This study will further the knowledge base regarding vestibular function in children with ADHD, and in conjunction with earlier work by Rabinowitz , study changes in vestibular function and balance in individuals through the lifespan. The hypotheses for this study are: (1) children with ADHD will have no significant differences in oculomotor performance when compared to an age matched control group; (2) children with ADHD will have significantly poorer performance in vestibular testing results when compared to an age matched control group; and (3) children with ADHT) will have significantly lower scores on the Bruininks-Oseretsky Test of Motor Proficiency Balance Subtest.

Materials and Methods

Forty children, ages 6-13 with a mean age of 9.27 participated in this study. Eighteen children had received the diagnosis of ADHD, and twenty-two children had not received an ADI{D diagnosis. All children were screened for any major illness, any history of head injury, and neurological disorders. Any diagnosis of conditions commonly co-morbid to ADHI), such as learning disabilities, were recorded. A questionnaire was developed according to DSM-1V3 criteria to screen all children for ADHD and correlate behavior ratings with diagnosis of ADHD.

All children were asked to abstain from the use of mood-altering chemicals, central or vestibular suppressing medications, or caffeine within 48 hours of testing. Children were recruited through word-of-mouth, school flyers, newspaper and in-house advertising at St. John's Hospital, Springfield IL.

Testing was performed at the Vestibular Clinic of the SIU School of Medicine, Division of Otolaryngology. Ocular motor testing was completed with a series of computer generated eye tracking tests, including saccade and smooth pursuit testing. The saccadic reflex uses the correction of a retinal positional error between foveal vision and a stimulus target within the peripheral visual field. Saccades were elicited by asking the subject to track a target that randomly appeared, disappeared, and reappeared in another location in the visual field (from 20 to 30 degrees). To examine smooth pursuit, the subject was asked to track a target moving in a pendular fashion in the visual field by matching target velocity with eye movement velocity, and was performed at frequencies of 0.1, 0.2, and 0.4 Hz. Recording was performed with a two- channel infra-red oculography system by Eye Dynamics, Inc. Vestibular function was assessed utilizing the Halmagyi "Head Thrust" test and the head- shake nystagmus test with infra-red goggles. The Halmagyi head thrust provides a method to examine the unilateral gain of a subject's vestibular ocular reflex (VOR). In this test, the subject focused on a distant point, and the examiner rotated the subject's head suddenly and rapidly in a small arc (10-20 degrees) to the left or right. This technique examined the ability of the subject's VOR to maintain gaze.12 13 Head shake nystagmus provides a method for examining for peripheral vestibular lesions. 14 In this test, the subjects vigorously shook their heads from side to side for 15-20 seconds. Eye movements were monitored and recorded with infra-red oculography.

Balance testing, including Romberg and the Balance section of the Bruininks-Oseretsky Test of Motor Proficiency was performed. The Romberg test measures the subject’s ability to stand with feet together and eyes closed. A sharpened Romberg, in which the subject places one foot behind the other with eyes closed was also performed. The Bruininks-Oseretsky Balance Sub-test was used to assess the subject’s ability to stand on one leg on the floor, stand on one leg on a balance beam, stand on one leg on a balance beam with eyes closed, walk forward on a line on the ground, walk forward on a balance beam, walk forward heel-to-toe on a line on the ground, and walk forward heel-to-toe on a balance beam. For each test, the scores received were compared to the age-matched normative scores obtained for this test.”

Computerized dynamic posturography testing, using the BalanceTrak 500® system was used to assess sensory organization and limits of stability. Posturography testing consisted of:

1) Normal Stability test; 2) Perturbed Stability test; and 3) Limits of Stability test. In the normal stability test, the subject stood on a platform with eyes open and then with eyes closed. In the perturbed stability test, the subject stood on a thick compliant foam rubber surface with eyes open and then with eyes closed. In the limits of stability test, the subject attempted to lean as far forward, backward, left, and right as possible using only ankle strategies while standing on a stable platform. This determines how far the subject could shift their center of gravity over their base of support In each test, a harness connected to a surrounding frame was used to support the subject in case of loss of balance to prevent falling. Normative values for this system had previously been determined.

Results

Patient Characteristics

Of the eighteen children with an ADHD diagnosis, 94% had a positive ADHD questionnaire following DSM-IV criteria. Ten percent of the children (ADHD=3, Normal=l) had been diagnosed with a learning disability. One of the children with ADHD (2.5%) bad a diagnosis of oppositional-defiant disorder. None of the children tested in this study had been diagnosed with conduct, anxiety, mood or motor disorders. Seven of the children were unable to abstain from caffeine (ADHD3, Nonnal4).

Vestibular Testing

No statistically significant difference was found between groups for Halmagyi head thrust or head shake nystagmus testing.

Ocular Motor Testing

No statistically significant difference was found between groups for saccades (Figure 1) or smooth pursuit. The mean gain for normal children at 0.1 Hz was 86.86, and 81.63 for children with ADHD. The mean gain at 0.2 Hz. was 86.55 for normal children and 82.65 for children with ADHD (Figures 2 and 3). In saccade testing, the mean peak velocity achieved for normal children was 412.82 degrees/second, and 416.78 for children with ADHD. The mean latency in the saccade test was 0.38 seconds for normal children and 0.39 for children with **ADHD (Figure 4).**

Posturography Testing

No statistically significant difference was found in the posturography testing. Children with ADHD performed slightly worse than normal children in the normal and perturbed stability tests. In the limits of stability tests, children with ADND performed slightly better (Figure 5).

Balance Testing

Children with ADHD performed significantly worse on the Bruininks-Oseretsky Motor Proficiency Balance Subtest (p=0.034). The age-matched mean score for children with ADNI) was -3.67 points below normal. The same score for the control group was -1.18 points below normal. The children with ADHD also showed greater variation in their scores (Figure 6). An examination of one task of the Bruininks-Oseretsky Balance Test, in which the children were asked to stand on one leg on the balance beam with their eyes closed and hands on their hips, revealed that scores improved with age (p0.003) and greater variability in scores was seen in children with ADHD (Figure 7).

The three children with ADHD who were unable to abstain from caffeine use within 48 hours of testing showed significantly poorer scores on balance testing (pO.O44). The fifteen children with ADHD who did not drink caffeine had a mean Bruininks-Oseretsky Balance Test score of -3.07, and the three children who did drink caffeine had a mean score of -6.67.

Discussion

The results of this study correlate well with earlier research done on children with ADHD. Our finding of poorer balance in children with ADH]) correlates with the findings in college-age individuals with ADHD found by Rabinowitz.2 Also, the trends in our research of poorer posturography results in children with ADEID correlate well with that done by ShumwayCook 5, in that posturography results were poorer in children with learning disabilities in her study, while VOR scores showed no significant difference.

One hypothesis to explain our results is the sensory-integration weakness theory, as proposed by Jean Ayres. Children with ADHD may be unable to properly integrate their visual, vestibular, neuromuscular and sensory information to a steady stream that the brain can readily interpret, which leads to the deficits in balance function and trends supporting deficits in ocular motor and posturography tbnctioning.4

A great deal of variability was seen in our results of the ADHD group as compared to the control group, indicating that the ADHD population could be very heterogeneous. Kimball'6 suggests a mechanism for heterogenicity with a proposal of two distinct deficiencies in CNS function, with one group of children hypothesized to have overinhibition of the vestibular nuclei by cortical centers, and the other with underinliibition of vestibular nuclei by cortical centers. Further testing with a larger subject pool would be necessary to confirm this hypothesis.

Conclusions

Statistically significant differences were seen in overall balance in the BruininksOseretsky Balance Subtest. Trends were seen in the posturography and ocular motor testing (0.1 and 0.2 Hz.), that support the hypothesis of deficits in the vestibular and ocular motor systems in children with ADH1D. We suspect that the lack of statistical significance in the petrography and ocular motor testing was largely due to small sample size, as well as the greater variation seen in ADHD children scores.

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Figure Legends

Figure 1: Ocular Motor Testing. Gain differences at 0.1, 0.2 and 0.4 Hz.

Figure 2: Ocular Motor Testing. Gain differences at 0.1 Hz.

Figure 3: Ocular Motor Testing. Gain differences at 0.2 Hz.

Figure 4: Ocular Motor Testing. Peak velocity of saccades achieved in degrees/second.

Figure 5: Posturography Testing. NSEO = Normal stability, eyes open test. NSEC Normal stability, eyes closed test. PSEO = Perturbed stability, eyes open test. PSEC = Perturbed stability, eyes closed test. LOS Limits of stability tests.

Figure 6: Balance Testing. Overall Bruininks-Oseretsky results as compared to age-matched normal scores.

Figure 7: Balance Testing. Bruininks-Oseretsky Eyes Closed Task Results.

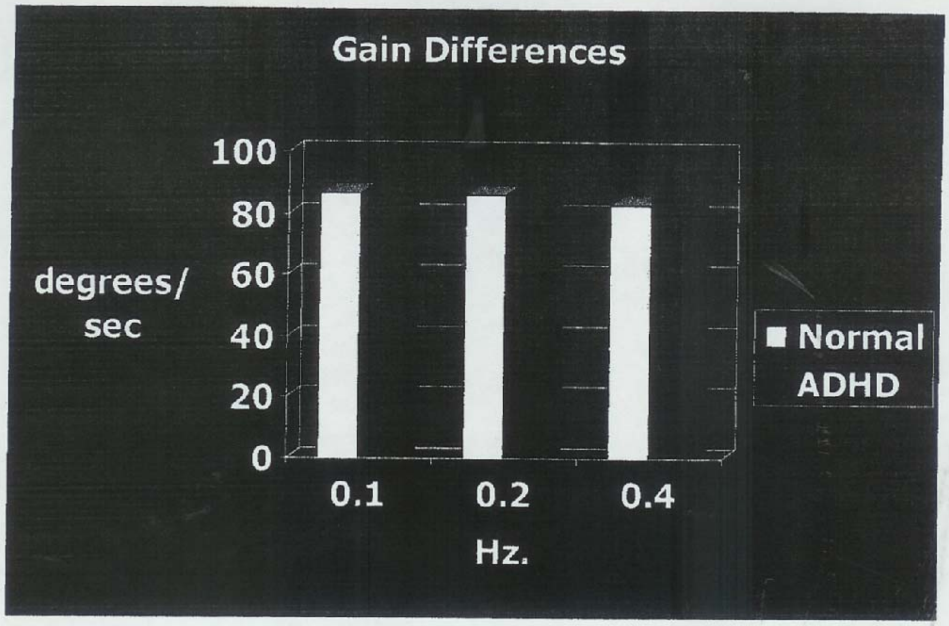

Gain Differences
100
80
60
40
20
0
degrees/
sec
Normal
ADHD
0.1
0.2
0.4
Hz.

Figure 1

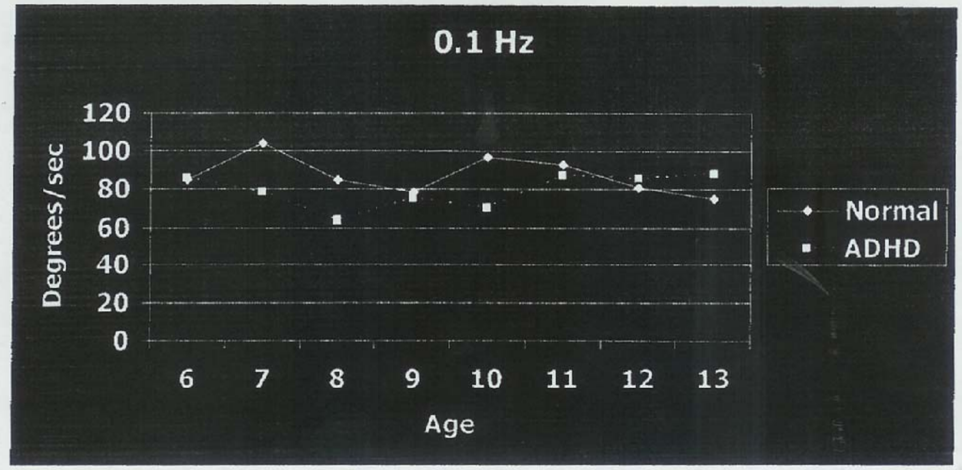

0.1 Hz
120
100
80
60
40
20
0
Degrees/sec
6
7
8
9
10
11
12
13
Age
Normal
ADHD

Figure 2

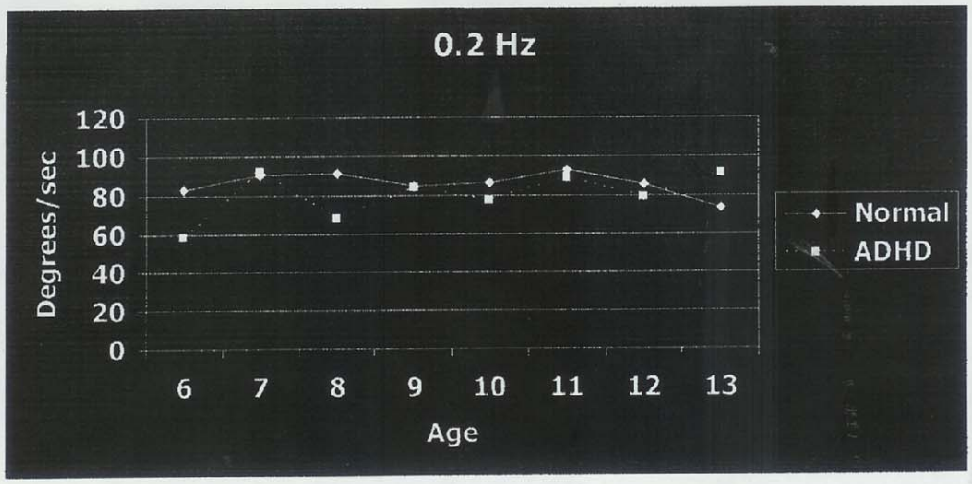

0.2 Hz
Degrees/sec
120
100
80
60
40
20
0
6
7
8
9
10
11
12
13
Age
Normal
ADHD

Figure 3

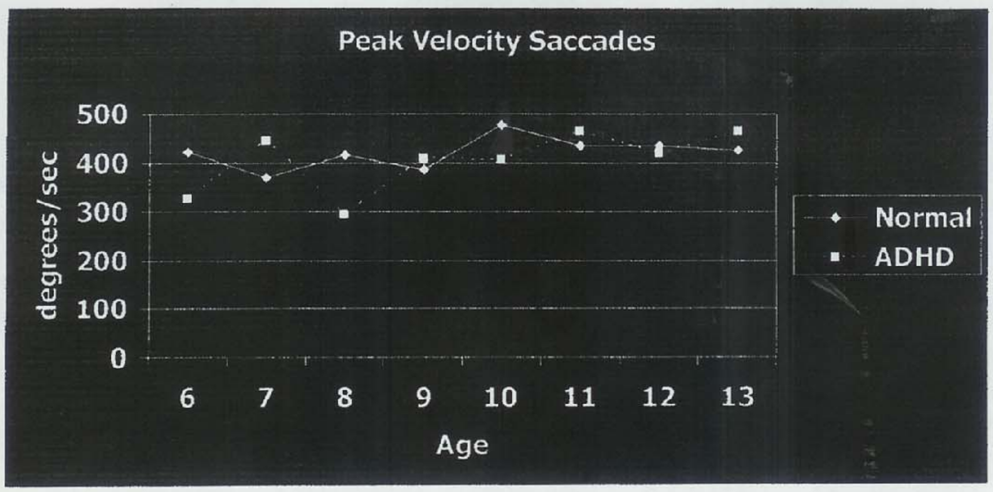

Peak Velocity Saccades
500
400
300
200
100
0
degrees/sec
6
7
8
9
10
11
12
13
Age
Normal
ADHD

Figure 4

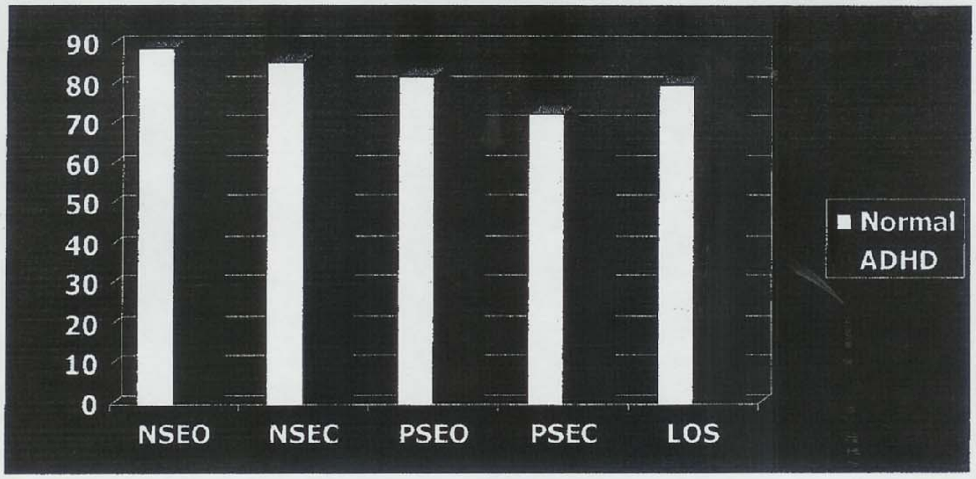


Figure 5

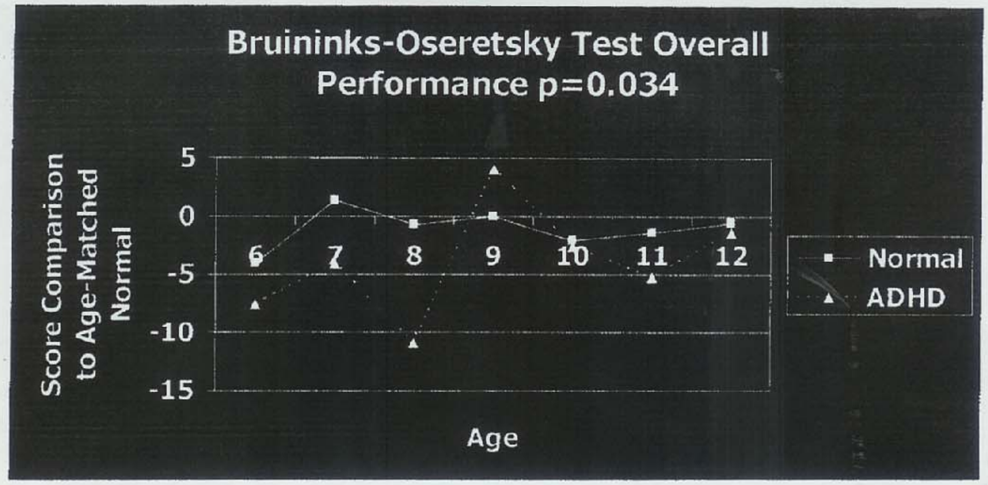
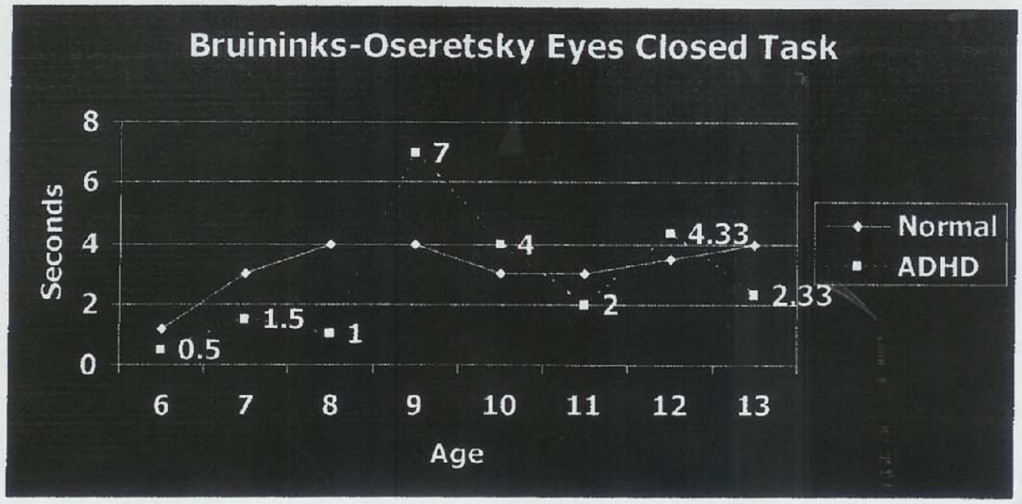

Bruininks-Oseretsky Test Overall Performance p=0.034
Score Comparison to Age-Matched Normal
5
0
-5
-10
-15
6
7
8
9
10
11
12
Age
Normal
ADHD

Figure 6



Bruininks-Oseretsky Eyes Closed Task
Seconds
Age
Normal
ADHD
0
2
4
6
8
6
7
8
9
10
11
12
13
0.5
1.5
1
7
4
2
4.33
2.33

Figure 7