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Academic Achievement in Adults with a History of Childhood Attention-Deficit/Hyperactivity Disorder: A Population-Based Prospective Study

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Abstract

Background—Previous research on the developmental course of ADHD is limited by biased clinic-referred samples and other methodologic problems. Thus, questions about adult academic outcomes associated with childhood ADHD remain unanswered.

Objective—To describe academic outcomes in adulthood among incident cases of research-identified childhood ADHD versus non-ADHD referents from a population-based birth cohort.

Design/Methods—Young adults with research-identified childhood ADHD (N=232; mean age 27.0 years; 72.0% male) and referents (N=335; mean age 28.6 years; 62.7% male) from a 1976–1982 birth cohort (N = 5699) were invited to participate in a follow-up study and were administered an academic achievement battery consisting of the Basic Reading component of the Woodcock-Johnson III Tests of Achievement (WJ-III) and the Arithmetic subtest of the Wide Range Achievement Test-Third Edition (WRAT3). Outcomes were compared between the two groups using linear regression models, adjusted for age, gender, and co-morbid learning disability (LD) status.

Results—Childhood ADHD cases scored from 3 to 5 grade equivalents lower on all academic tests compared to referents, with mean (SD) standard scores of 95.7 (8.4) versus 101.8 (8.1) in Basic Reading; 95.0 (9.3) versus 101.9 (8.5) in Letter-Word Identification; 98.2 (8.6) versus 103.2 (9.2) in Passage Comprehension; 95.7 (9.1) versus 100.9 (9.0) in Word Attack; and 87.8 (12.9) versus 98.0 (12.0) in Arithmetic.

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Conclusions—This is the first prospective, population-based study of adult academic outcomes of childhood ADHD. Our data provide evidence that childhood onset ADHD is associated with long term underachievement in reading and math that may negatively impact ultimate educational attainment and occupational functioning in adulthood.

Keywords

ADHD; attention-deficit/hyperactivity disorder; academic achievement; reading; math; adult outcomes

INTRODUCTION

Attention-Deficit/Hyperactivity Disorder (ADHD), characterized by developmentally inappropriate and disabling levels of inattention, impulsivity, and hyperactivity that impair functioning across settings, is the most prevalent childhood neurobehavioral disorder.^{1–3} We previously reported that among individuals with childhood ADHD, 29% continue to meet criteria for ADHD as adults, and a majority of adults with a history of childhood ADHD meet criteria for at least one other psychiatric disorder, regardless of whether their childhood ADHD persisted into adulthood.⁴ In addition to causing social impairments that contribute to long term psychosocial adversity, ADHD profoundly and negatively impacts academic achievement in children and adolescents.^{5, 6} In order to more fully understand the long-term impact of childhood ADHD across the lifespan, it is important to more precisely determine the extent of academic underachievement into adulthood.

We previously reported the presence of learning disabilities (LD) among the members of a 1976–1982 birth cohort.^{7, 8, 9} We have also reported on school outcomes among children with ADHD in this birth cohort, and the association between stimulant medication treatment and academic outcomes through age 19 years, including improved reading scores and reduced rates of school absenteeism and grade retention.^{10, 11} However, the potential impact of comorbid LD status and childhood stimulant medication treatment on adult academic achievement outcomes is unknown.

Previous research on the developmental course of ADHD has been limited by biased, clinic-referred samples and other methodological problems. Previous prospective studies have typically depended on outcomes for childhood ADHD cases referred to psychiatric clinics and specialty treatment programs, and therefore may not be representative of the general population of individuals with ADHD.^{12–20} Other methodological problems have included dependence on adult recall of childhood ADHD, studies limited to boys, small sample sizes, and diagnostic criteria that are based on the presentation of ADHD in childhood.^{12–17, 19, 20} Previous studies with similar methodological problems have suggested high rates of comorbid academic underachievement in adults with a history of ADHD or ADHD symptoms.^{12, 21–30} These studies have shown that adults with ADHD are at increased risk for failure to graduate from high school, low rates of post-high school education, and associated lower income, poor work performance, and unstable employment. Given that the majority of these previous, longitudinal studies have relied on childhood or adult ADHD cases referred to psychiatric clinics or specialty treatment programs, the high rates of

academic underachievement reported may not be found in the entire population of adults with a history of childhood ADHD.

Thus, the methodological limitations of these prior studies preclude an accurate description of the developmental course and academic outcomes for the majority of children with ADHD. Further, no study to date has reported on academic achievement in a population-based cohort of childhood ADHD cases followed into adulthood. Therefore, our objectives were to: 1) prospectively describe academic outcomes in adulthood among research-identified childhood ADHD cases compared to non-ADHD controls from a population-based birth cohort, 2) explore the relationship between stimulant medication treatment and adult academic achievement among our ADHD cases, and 3) determine whether or not childhood learning disability (LD) status modifies adult academic outcomes among childhood ADHD cases.

METHODS

Study Setting

The setting for this study was Rochester, Minnesota, which is geographically isolated in southeastern Minnesota, and virtually all medical care for residents is provided by Mayo Clinic, Olmsted Medical Center and their 3 affiliated hospitals. The infrastructure for this population-based research was provided by resources of the Rochester Epidemiology Project, where all medical diagnoses and surgical procedures are recorded and indexed for computerized retrieval.³¹ In addition, for this study, all 41 public and private schools in Minnesota Independent School District 535 (city of Rochester school system) participated in a contractual research agreement that provided permission to access cumulative educational records for every child from the 1976–1982 Rochester, MN birth cohort. The study was approved by the IRBs of the Mayo Clinic and Olmsted Medical Center, and written informed consent was obtained from all participants in the prospective portion of this study.

Subjects

Birth Cohort—Subjects for this study were members of a birth cohort of all children born between January 1, 1976 and December 31, 1982 to mothers residing in the townships comprising Minnesota Independent School District 535, who continued to live in Rochester until at least 5 years of age, and who granted permission for use of their medical records for research purposes (N=5718).

Identification of Childhood ADHD Cases and Referents in Previous,

Retrospective Study—As described in previous reports,^{1, 4, 32} subjects were defined as having research-identified childhood ADHD if their school and/or medical records included various combinations of the following 3 different categories of information: (1) documentation in medical and school records of behavioral symptoms consistent with the criteria for ADHD from the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition*³³(DSM-IV TR); (2) positive ADHD questionnaire results; and (3) documented clinical diagnoses of AD/HD. Research diagnostic criteria for childhood ADHD were met at a mean age of 10.4 years. Non-ADHD referents were identified from the remaining

members of the birth cohort who were in the community after 5 years of age, and who had not fulfilled research criteria for childhood ADHD (N=4946); subjects with severe intellectual disability (N=19) or who denied access to their medical records for research purposes (N=369) were excluded from the study.

Identification of Comorbid Learning Disability—The presence of a comorbid learning disability (LD) among members of the 1976–1982 birth cohort has been reported previously.^{7–9} Since we had access to the results of all academic achievement tests and the results of all cognitive tests administered to birth cohort members at any point during childhood, we were able to establish the presence of LD in reading, math, or written language, respectively, by assessing whether subjects met the criteria for either of two regression-based formulas or one non-regression-based discrepancy formula using individually administered IQ and achievement scores in reading, math, or written language.^{7–9}

Information about Childhood Treatment with Stimulant Medication—We previously reviewed the medical records of all ADHD incidence cases for information about childhood treatment with stimulant medication.³⁴ For each documented stimulant medication treatment episode documented, the dose and associated start and stop dates (based on the dates of visits at which medications were prescribed and when prescription refills were written) were abstracted. The cumulative duration of stimulant medication treatment was calculated by summing the durations of these individual treatment episodes. The dose of each medication was converted to methylphenidate equivalent units (MEUs).³⁴ For each subject, the average daily dose of stimulant medication in MEUs was calculated as a weighted average of the doses; each dose was weighted by the duration of use.

Recruitment for Prospective Study—Of the 379 subjects with childhood ADHD identified in our retrospective study, 362 who provided continued permission to access their medical records for research were invited to participate in the prospective adult outcome study. Subject recruitment included mailings with follow-up phone calls. A random sample of 801 adults from the same birth cohort were also invited to participate, ensuring enrollment of sufficient non-ADHD referents. All participants in the prospective study were administered the Mini International Neuropsychiatric Interview (M.I.N.I.), including the module for adult ADHD.^{35, 36} A childhood ADHD incidence case was classified as having persistent, adult ADHD if the number of ADHD symptoms exceeded 2 standard deviations above the mean number of current inattentive (i.e., 4 symptoms) *and/or* hyperactive/impulsive symptoms (i.e. 4 symptoms) endorsed by the non-ADHD referents and endorsement of the M.I.N.I. statement that ADHD symptoms were having a significant adverse impact in two or more settings. We previously reported that 5 referent subjects who participated in the prospective study were reclassified as childhood ADHD cases, therefore all subsequent analyses included these 5 subjects as childhood ADHD cases.⁴

Academic Achievement Measures

All participants who participated in person were administered an academic achievement battery consisting of the Basic Reading component of the Woodcock-Johnson III Tests of

Achievement (including Letter-Word Identification, Passage Comprehension, and Word Attack subtests)³⁷ and the Arithmetic subtest of the Wide Range Achievement Test 3 (WRAT-3).³⁸ These instruments provided raw scores, percentile scores, and standard scores. We also determined the grade equivalent for the mean raw score of each academic domain tested.

Woodcock-Johnson III Tests of Achievement—The Woodcock-Johnson III Tests of Achievement (WJ-III) provide a comprehensive set of individually administered, norm-referenced tests for measuring academic achievement. The national standardization included over 8000 individuals from 2 to 90 years of age, whose demographic and community characteristics closely match those of the general US population.³⁷

The *Letter-Word Identification* subtest measures word identification/phonetic skills. The individual is only required to pronounce the words correctly but is not required to know the meaning of any word. The items become increasingly difficult as the selected words appear less and less frequently in written English.³⁷

The *Passage Comprehension* subtest requires the individual to read a short passage and identify a missing key word that makes sense in the context of the passage. The items become increasingly difficult by increasing passage length, level of vocabulary, and complexity of syntactic and semantic cues.³⁷

The *Word Attack* subtest measures skill in applying phonic and structural analysis to the pronunciation of unfamiliar printed words. The items require the individual to read aloud letter combinations that are phonically consistent, or regular, patterns in English orthography but are nonwords or low frequency words. The items become more difficult as the complexity of the nonwords increases.³⁷

The *Basic Reading Skills* cluster is a combination of the Letter-Word Identification and Word Attack subtests and provides a measure of basic reading skills. It is an aggregate measure of sight vocabulary, phonics, and structural analysis.³⁷

Wide Range Achievement Test 3—The Wide Range Achievement Test 3 (WRAT 3) Arithmetic subtest is an individually administered, norm-referenced test for measuring academic achievement in counting, reading number symbols, solving oral problems, and performing written arithmetic computations. Norms for this test were obtained from a representative sample of nearly 5000 individuals from all sections of the United States.³⁸

Statistical Methods

The data were analyzed using the SAS version 9.3 software package (SAS Institute, Inc.; Cary, NC). Characteristics were compared between participating and non-participating subjects with childhood ADHD (and between participant subjects with childhood ADHD and participating non-ADHD referents) using the chi-square test for nominal variables, the two-sample t-test for continuous variables, and the Wilcoxon rank sum test for ordinal categorical variables. Linear regression models were fit to compare the standard scores from academic achievement tests between participating subjects with childhood ADHD and

participating referents. Models were fit with and without adjustment for age, gender, maternal education at birth, and presence of comorbid reading or math LD prior to 19 years of age. Similar analyses were performed among the subjects with childhood ADHD comparing those treated versus not treated with stimulants for 3 months. The Spearman rank correlation coefficient was used to assess the correlation between academic achievement scores and stimulant treatment parameters among childhood ADHD cases treated with stimulants for 3 months. All calculated p-values were two-sided and p-values less than 0.05 were considered statistically significant.

RESULTS

Prospective Study Participants

Among the 367 eligible childhood ADHD cases, 232 (167 males, 65 females; mean (SD) age 27.0 (2.6) years) or 63.2% participated in the prospective study. Participants and non-participants were compared on multiple factors, including gender, age, race, high school graduation status, address distance, receipt of stimulant medication during childhood, psychiatric diagnoses prior to 18 years of age, any LD before 19 years of age, maternal age at birth, maternal education, and maternal marital status.⁴ Of these factors, participating and non-participating adults with childhood ADHD differed only on high school graduation rates (84.3% for participants vs 64.8% for non-participants; $p < 0.01$).⁴ A total of 801 non-ADHD referents from the same birth cohort were invited to participate, yielding 335 participants (210 males, 125 females; mean (SD) age 28.6 (2.2) years). Characteristics of the study participants at birth and at the time of study participation are contrasted between the childhood ADHD cases and non-ADHD referents in Table 1. Compared to participating non-ADHD referents, the participants with childhood ADHD were more likely to be slightly younger (mean age, 27 vs. 28.6 years), male (72 vs. 62.7%), have parents with less years of education at birth, more likely to have a reading or math LD by 19 years of age, and have a lower academic degree at participation (all $p < 0.05$).

Adult Academic Achievement Outcomes

Academic achievement test scores are summarized in Table 2. Among the participants who completed academic achievement testing, the research-identified childhood ADHD cases scored lower on all academic achievement tests compared to non-ADHD referents. The differences between cases and referents were similar for males and females (data not shown). ADHD cases scored lower, even after adjusting for age, gender, level of maternal education at birth, and LD status ($p < 0.05$; Table 2).

Although mean standard scores on all subtests for both groups were in the average range, and while it is important to note that relatively small changes in raw scores can lead to larger changes in grade equivalents on the Woodcock-Johnson III Tests of Achievement, in terms of the grade equivalents of mean raw scores, ADHD cases scored nearly 3 grade levels below referents in Letter-Word Identification (11.6 versus 15.4 grade equivalent) and Word Attack (7.5 versus 10.2 grade equivalent), at least 5.5 grade levels below referents in Passage Comprehension (12.5 versus > 18.0 grade equivalent), and 3.4 grade levels below referents in overall Basic Reading (9.8 versus 13.2 grade equivalent). ADHD cases scored in a low

average range on the WRAT3 Arithmetic test, scoring at only a 7th grade level versus a high school level for referents (please note that the scoring for the WRAT3 Arithmetic test provides numeric grade equivalents through 8th grade; raw scores between 40 and 46 are designated only as a “high school” level grade equivalent). The effect size of the differences in these academic achievement scores between adults with a history of childhood ADHD and non-ADHD referents ranged from medium to large (Cohen’s *d* values ranging from -0.55 to -0.82).

Impact of Learning Disabilities on Adult Academic Achievement

Among the childhood ADHD cases, subjects who met criteria for a LD in reading prior to 19 years of age scored lower, on average, on all 4 of the reading academic achievement tests completed as an adult compared to those without a reading LD (Table 3, Cohen’s *d* values range from -0.66 to -0.89). The same pattern was observed among those with and without a LD in math when comparing the scores on the WRAT-3 arithmetic test. Furthermore, the average WJ-III reading achievement scores for subjects with childhood ADHD without reading LD were significantly less than the average scores for non-ADHD referents, however, these average differences were less than 3 points and did not retain statistical significance after adjusting for age, sex, and level of maternal education at birth. On the other hand, subjects with childhood ADHD without a math LD scored significantly lower than non-ADHD referents on the WRAT-3 arithmetic test (Table 3), even after adjusting for the three covariates (adjusted means, 91.9 vs 97.2, $p < 0.001$).

Stimulant Treatment During Childhood and Adult Academic Achievement

Of the 232 research-identified childhood ADHD cases, 146 were treated with stimulants for 3 months between the ages of 2 and < 21 years of age, 75 were either not treated or treated for < 3 months, and 11 were treated with stimulants for an unknown duration. Among the 146 cases, the median age at onset of treatment was 9.6 years (interquartile range [IQR], 7.7, 13.0) and the median duration of treatment was 44.0 months (IQR, 20.8, 79.3). During this time, the overall median for the average daily dose of stimulants was 24.5 MEUs (IQR, 19.9, 31.9). Academic achievement test scores were not significantly different between the treated and untreated subjects (Table 4). Table 5 summarizes the correlation between the academic achievement scores and stimulant treatment parameters for the 146 cases who were treated with stimulants for 3 months. Average daily dose ($r = 0.24$) and duration of treatment ($r = 0.16$) were positively, but weakly, correlated with arithmetic achievement (Figure 1). At the time of study participation, 23 (9.9%) of the 232 research-identified ADHD cases reported currently taking ADHD medications. Of the 75 treated with stimulants for 3 months during childhood, 19 reported currently taking stimulants at the time of study participation.

Persistent Adult ADHD and Adult Academic Achievement

As previously reported,⁴ among the 232 participating childhood ADHD cases, 68 fulfilled criteria for adult ADHD (29.3 %, 95% CI 23.5–35.2). Rates of persistent ADHD were similar for males (29.3%, 95% CI 22.4–36.3) and females (29.2%, 95% CI 18.2–40.3). If the M.I.N.I. requirement for self-report of adverse impact of ADHD symptoms were disregarded, the rate of persistent ADHD increased to 38.8% (95% CI 32.5–45.1). As shown

in Table 6, academic achievement test scores were not significantly different between the childhood ADHD cases with and without ADHD that persisted into adulthood.

DISCUSSION

We have previously described risk factors for ADHD, childhood co-morbidities, treatment history, and educational outcomes through age 19 years for this population-based birth cohort of childhood ADHD cases.^{10, 11, 39–43} We have found that compared to referents without ADHD, childhood ADHD cases have lower reading achievement test scores, are more likely to be retained in grade, and are more likely to drop out of school.¹⁰ We have also found that individuals with childhood ADHD are more likely to have specific learning disabilities in reading and written language.^{42, 43} The study reported here extends our findings of adverse academic outcomes among individuals with childhood ADHD and confirms that childhood ADHD is associated with significant academic underachievement in adulthood. We also found that academic achievement test scores were not significantly different between stimulant treated and untreated subjects, that academic scores were lower for ADHD cases even after controlling for co-morbid learning disabilities, and that those with both ADHD and LD had the lowest academic achievement scores. Finally, we found that adult ADHD status was not related to academic achievement scores, indicating that these scores primarily reflect the impact of ADHD on acquisition of academic skills in childhood and adolescence.

We found that adults with childhood ADHD from our population-based birth cohort scored in a low average range in arithmetic, but their mean basic reading scores were in an average range. However, compared to referents, the grade equivalents for mean raw scores for individuals with childhood ADHD were 3 to 5 grade levels below those of referents without ADHD. At a mean age of 27 years, adults with childhood ADHD scored at only a 9th grade level in basic reading and a 7th grade level in arithmetic, compared to a 13th grade equivalent in basic reading and a high school level for arithmetic in referents. While it is important to note that relatively small changes in raw scores can lead to larger changes in grade equivalents on tests of academic achievement, the effect size of the differences in these academic achievement scores between adults with a history of childhood ADHD and non-ADHD referents ranged from medium to large (see Table 2). Interestingly, both ADHD cases and referents had relative difficulty in the Word Attack section of the Woodcock-Johnson III Tests of Achievement, with the ADHD cases scoring at a 7th grade level and the referents scoring at a 10th grade level. These relative weaknesses in Word Attack, a subtest measuring ability to phonetically decode pseudowords, may well be attributable to the Minnesota Independent School District 535's decision to shift from a phonics-based to a whole word-based method of reading instruction at the time that these subjects were in early elementary school.

Academic underachievement in mathematics and reading have been demonstrated to have substantial negative associations with academic motivation, duration of education, and adult socioeconomic status.⁴⁴ Further, we have previously reported that adults with childhood ADHD are at increased risk for psychosocial adversity, regardless of adult ADHD status.⁴

Thus, our finding that adults with childhood ADHD exhibit academic underachievement places them at double jeopardy of poor long term psychosocial outcomes.

We found that ADHD cases scored lower, even after adjusting for age, gender, maternal education, and LD status ($p < 0.001$; Table 2). Thus, ADHD alone, even controlling for comorbid LD, remains a risk factor for poor long-term academic outcomes. It has been reported that executive dysfunctions are correlates of ADHD across age groups,⁴⁵ and executive function deficits, with or without the presence of comorbid LD, negatively impact school performance.⁴⁶ We have also previously demonstrated the negative impact of ADHD on reading achievement, school absenteeism, grade retention, and school drop-out.¹⁰ Thus, these findings highlight the broader impact of ADHD on school function that may translate to poor long-term academic achievement outcomes.

In our previous study on school outcomes through age 19 years, we found that receipt of special education services was not associated with improved outcomes.¹¹ As we described in that study, this does not imply that receipt of special education services is ineffective; rather, as we asserted at the time, we believe that intervention likely is initiated too late and is insufficiently intensive. Previous studies have consistently demonstrated the importance of early, intensive intervention for neurodevelopmental disorders, including learning disorders. We continue to believe that earlier and more intensive intervention is warranted based on other studies of this issue and the implications for long-term, adverse academic achievement outcomes for children with ADHD. Our current data provide evidence for the need for aggressive early intervention measures to prevent academic underachievement in children with ADHD. Many children with ADHD receive accommodations at school under Section 504 of the Rehabilitation Act, but these accommodations do not include remedial academic instruction.⁴⁷ Unfortunately, while the Individuals with Disabilities Education Act qualifies students with ADHD for special education services under the “Other Health Impairment” category, very few children with ADHD actually access remedial academic instruction, unless they have a co-morbid LD.⁴⁸ It is important to note that LD services through an IEP are much more costly than accommodations under a 504 plan. However, our data clarify the need for thorough evaluations of learning status and provision of academic supports to children with ADHD regardless of whether the child also meets criteria for LD. More liberal inclusion of children with ADHD in remedial academic instruction, particularly in the early elementary school years, would most likely result in improved adult academic achievement.⁴⁹

While, in this study, we found that stimulant medication treatment had no clinically significant effect on adult academic achievement outcomes, it is very important to note the very limited duration of stimulant medication treatment for our study subjects. It has been suggested that early and closely monitored longitudinal medical treatment of ADHD may well improve adult academic achievement,⁵⁰ and given our previous findings that even the limited stimulant medication treatment received by our study subjects with ADHD was associated with improved reading achievement, decreased school absenteeism, and decreased grade retention,¹¹ it would appear most likely that if stimulant medication treatment was continued throughout childhood and adolescence, then a meaningful impact on adult academic outcomes would be observed. Unfortunately, our data do not allow us to

make this determination. In addition, since so few of the adults in our study were currently receiving medical treatment for their ADHD, it was not possible to assess the extent to which adult treatment may have impacted academic achievement scores.

Our study has several potential limitations. First, the initial, retrospective identification of ADHD cases in the birth cohort may have been incomplete; however, the comprehensive access to relevant information from school and medical records and use of rigorous research criteria suggest that it is unlikely that we missed a significant number of childhood ADHD cases.³² Second, our prospective outcome study included only 61% of the original cohort of childhood ADHD cases; however, participants and non-participants differed only on high school graduation rates, with participants being more likely to graduate than non-participants. Therefore, our findings most likely represent an underestimate of the extent of academic underachievement experienced by adults with a history of childhood ADHD.

Finally, at the time of our original, retrospective study, Rochester, Minnesota was primarily a 95% white, middle class community, so inferences to more diverse populations may be limited; however, residents of Rochester have easy access to medical care and comprise a homogeneous population, thus minimizing confounding effects of SES, ethnicity, and race on our study findings. Considering this information, it appears most likely that the magnitude of the academic underachievement experienced in this birth cohort would be more severe in populations with additional psychosocial challenges.

CONCLUSIONS

Previous research on the developmental course of ADHD, while limited by biased, clinic-referred samples and other methodological problems, has reported negative educational, financial, vocational, and psychiatric outcomes in adulthood. This population-based, epidemiologic study of a more representative general population of individuals with ADHD, unfortunately confirms that adults with childhood ADHD experience academic underachievement in adulthood. Our findings reaffirm that ADHD should no longer be viewed only as a disorder primarily affecting the behavior and learning of children.⁴ Our data provide further evidence that ADHD is a chronic health problem, and it confers increased risk for academic underachievement and its associated psychosocial and socioeconomic complications across the lifespan. Based on our current and previous findings, in order to improve long term outcomes for children with ADHD, it is most critical that: 1) associated learning disabilities in children with ADHD be identified and intensive evidenced-based remedial educational services be initiated as early as possible, and 2) treatment with evidence-based medical and behavioral interventions be consistently maintained throughout childhood and adolescence. Our findings have important implications for both the effectiveness of special educational services and medical care provided to children with ADHD, as well as the system of care required to meet the needs of individuals with ADHD across the lifespan.

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Abbreviations

ADHD	attention-deficit/hyperactivity disorder
LD	learning disability
DSM-IV TR	Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition
WJ-III	Woodcock Johnson III Tests of Achievement
WRAT3	Wide Range Achievement Test 3

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Figure 1. Relationship between WRAT-3 arithmetic standard scores and duration of stimulant treatment during childhood among 141 research-identified childhood ADHD cases treated with stimulants for 3 months.

Table 1

Characteristics of study participants at birth and at time of study participation, by research-identified childhood ADHD status.

Characteristic	Childhood ADHD cases (N=232)	Non-ADHD referents (N=335)	P-value [‡]
Age at participation, mean (SD)	27.0 (2.6)	28.6 (2.2)	<0.001
Male gender, n (%)	167 (72.0)	210 (62.7)	0.021
Caucasian race, n (%)	231 (99.6)	329 (98.2)	0.15
<u>Parental characteristics at birth</u>			
Maternal age, mean (SD)	26.0 (4.6)	26.8 (4.4)	0.027
Paternal age, mean (SD)	28.6 (5.0)	29.0 (5.5)	0.35
Maternal years of education, n (%)			0.010
<12	13/212 (6.1)	17/302 (5.6)	
12	88/212 (41.5)	96/302 (31.8)	
13–15	74/212 (34.9)	110/302 (36.4)	
16+	37/212 (17.5)	79/302 (26.2)	
Paternal years of education, n (%)			0.016
<12	10/199 (5.0)	13/290 (4.5)	
12	74/199 (37.2)	78/290 (26.9)	
13–15	51/199 (25.6)	80/290 (27.6)	
16+	64/199 (32.2)	119/290 (41.0)	
Married at birth, n (%)	212 (91.4)	313 (93.4)	0.36
<u>Educational characteristics</u>			
Any reading disability prior to age 19, n (%)	111 (47.8)	33 (9.9)	<0.001
Any math disability prior to age 19, n (%)	141 (60.8)	26 (7.8)	<0.001
Highest educational degree, n (%)			<0.001
Doctoral or Master's degree	10 (4.3)	37 (11.0)	
Four-year college degree	38 (16.4)	143 (42.7)	
Associate degree	38 (16.4)	46 (13.7)	
Adult diploma	5 (2.2)	2 (0.6)	
GED	26 (11.2)	14 (4.2)	
High School	105 (45.3)	90 (26.9)	
No degree	10 (4.3)	3 (0.9)	

[‡] Comparisons were evaluated using the two-sample t-test for age, the Wilcoxon rank sum test for level of education, and the chi-square test for all other variables.

Table 2

Summary of academic achievement scores among study participants, by research-identified childhood ADHD status.

Academic achievement measure	Childhood ADHD Cases (N=232)	Non-ADHD Referents (N=335)	Cohen's d for the standard score [‡]		P-value	
			Mean standard score (SD) GE of mean raw scores	Unadjusted models [‡]	Adjusted models [‡]	
<u>WJ-III standard scores, N</u>	215	329				
Basic reading skills	95.7 (8.4)	101.8 (8.1)	-0.75	<0.001	0.040	
	9.8	13.2				
Letter-word identification	95.0 (9.3)	101.9 (8.5)	-0.78	<0.001	0.015	
	11.6	15.4				
Passage comprehension	98.2 (8.6)	103.2 (9.2)	-0.55	<0.001	0.032	
	12.5	> 18.0				
Word-attack	95.7 (9.1)	100.9 (9.0)	-0.57	<0.001	0.20	
	7.5	10.2				
<u>WRAT-3 standard scores, N</u>	215	329				
Arithmetic	87.8 (12.9)	98.0 (12.0)	-0.82	<0.001	<0.001	
	7	High School [^]				

GE, grade equivalent; WJ, Woodcock-Johnson; WRAT-3, Wide Range Achievement test-third edition; LD, learning disability.

[‡] Cohen's d is the difference between the two group means for the standard scores divided by the pooled standard deviation.

[‡] The linear regression models for the WJ-III scores were adjusted for age, sex, level of maternal education at birth and presence of reading LD prior to 19 years of age, whereas the model for the WRAT-3 scores were adjusted for the same first three covariates and the presence of math LD prior to 19 years of age.

[^] Note, raw scores on WRAT3 Arithmetic test between 40 and 46 are designated with only a "high school" grade equivalent.

Table 3

Summary of academic achievement scores among study participants, by research-identified childhood ADHD status and learning disability status.

	Childhood ADHD cases (N=232)		Non-ADHD Referents (N=335)	Childhood ADHD: with LD vs. without LD		Childhood ADHD without LD vs. Non-ADHD referents			
	LD [†]	No LD		Cohen's d [‡]	Unadjusted models p-value	Adjusted models p-value [*]	Cohen's d [‡]	Unadjusted models p-value	Adjusted models p-value [*]
	Mean standard score (SD)			Cohen's d [‡]	Unadjusted models p-value	Adjusted models p-value [*]			
<u>WJ-III standard scores, N</u>	107	108	329						
Basic reading skills	92.4 (7.0)	99.0 (8.5)	101.8 (8.1)	-0.85	<0.001	<0.001	-0.35	0.002	0.23
Letter-word identification	91.2 (7.7)	98.7 (9.2)	101.9 (8.5)	-0.89	<0.001	<0.001	-0.36	0.001	0.19
Passage comprehension	95.5 (6.9)	101.0 (9.3)	103.2 (9.2)	-0.67	<0.001	<0.001	-0.24	0.034	0.07
Word-attack	92.8 (8.1)	98.5 (9.1)	100.9 (9.0)	-0.66	<0.001	<0.001	-0.26	0.020	0.42
<u>WRAT-3 standard scores, N</u>	133	82	329						
Arithmetic	84.8 (12.0)	92.6 (12.8)	98.0 (12.0)	-0.63	<0.001	<0.001	-0.44	<0.001	<0.001

GE, grade equivalent; LD, learning disability; WJ, Woodcock-Johnson; WRAT-3, Wide Range Achievement test-third edition;

[†]The results for the WJ-III scores were stratified by the presence of reading LD, whereas the results for the WRAT-3 scores were stratified by the presence of math LD.

[‡]Cohen's d is the difference between the two group means for the standard scores divided by the pooled standard deviation.

^{*}The linear regression models for the WJ-III scores were adjusted for age, sex, and level of maternal education at birth.

Table 4

Summary of academic achievement scores among research-identified childhood ADHD cases, by stimulant treatment status.

Academic achievement measure, mean standard score (SD)	Treated with stimulants for 3 months [†]		Cohen's d for the standard score [‡]	P-value	
	Yes (N=146)	No (N=75)		Unadjusted models	Adjusted models [*]
WJ-III standard scores, N	141	65			
Basic reading skills	95.4 (9.0)	96.5 (7.3)	-0.14	0.37	0.97
Letter-word identification	94.6 (9.9)	95.9 (8.0)	-0.14	0.36	0.99
Passage comprehension	97.9 (8.3)	98.7 (9.4)	-0.10	0.51	0.90
Word-attack	95.4 (9.4)	96.6 (8.5)	-0.13	0.39	0.86
WRAT-3 standard scores, N	141	65			
Arithmetic	87.2 (13.1)	89.3 (11.7)	-0.17	0.27	0.45

WJ, Woodcock-Johnson; WRAT-3, Wide Range Achievement test-third edition; LD, learning disability.

[†] Of the 232 participating subjects with research-identified childhood ADHD, the duration of stimulant usage between 2 and <21 years of age was not documented for 11 subjects.

[‡] Cohen's d is the difference between the two group means for the standard scores divided by the pooled standard deviation.

^{*} The linear regression models for the WJ-III scores were adjusted for age, sex, level of maternal education, and presence of reading LD prior to 19 years of age, whereas the models for the WRAT-3 scores were adjusted for the same first three covariates and the presence of math LD prior to 19 years of age.

Table 5

Correlation between academic achievement scores and stimulant treatment parameters among research-identified childhood ADHD cases treated with stimulants for 3 months.

Academic achievement measure [†]	Spearman correlation coefficient [‡]		
	Age at onset of treatment	Average daily dose	Months of treatment
<u>WJ-III standard scores</u>			
Basic reading skills	−0.03	0.20	0.11
Letter-word identification	−0.01	0.20	0.09
Passage comprehension	0.02	0.18	0.10
W-J Word-attack	−0.03	0.13	0.08
<u>WRAT-3 standard scores</u>			
Arithmetic	0.02	0.24	0.16

WJ, Woodcock-Johnson; WRAT-3, Wide Range Achievement test-third edition.

[†] Of the 146 participating subjects with research-identified childhood ADHD who were treated with stimulants for 3 months between 2 and <21 years of age, 141 completed the WJ-III and WRAT assessments.

[‡] Given the sample size, correlations values > |0.15| are significantly different from zero (p<0.05).

Table 6

Summary of academic achievement scores among research-identified childhood ADHD cases, with and without ADHD that persisted into adulthood.

Academic achievement measure, mean standard score (SD)	Persistent adult ADHD		Cohen's d for the standard score [†]	P-value	
	Yes (N=68)	No (N=164)		Unadjusted models	Adjusted models [‡]
WJ-III standard scores, N	61	154			
Basic reading skills	97.1 (8.9)	95.1 (8.2)	0.24	0.11	0.55
Letter-word identification	96.0 (10.0)	94.6 (9.0)	0.15	0.32	0.92
Passage comprehension	98.1 (9.0)	98.3 (8.5)	-0.02	0.91	0.49
Word-attack	97.7 (9.5)	94.9 (8.8)	0.31	0.04	0.23
WRAT-3 standard scores, N	61	154			
Arithmetic	87.0 (13.5)	88.1 (12.7)	-0.08	0.58	0.28

WJ, Woodcock-Johnson; WRAT-3, Wide Range Achievement test-third edition; LD, learning disability.

[†] Cohen's d is the difference between the two group means for the standard scores divided by the pooled standard deviation.

[‡] The linear regression models for the WJ-III scores were adjusted for age, sex, level of maternal education, and presence of reading LD prior to 19 years of age, whereas the models for the WRAT-3 scores were adjusted for the same first three covariates and the presence of math LD prior to 19 years of age.