

ADHD at Age 7 and Functional Impairments at Age 10

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abstract

BACKGROUND AND OBJECTIVES: Attention-deficit/hyperactivity disorder (ADHD) cohort studies have typically involved clinical samples and have usually recruited children across wide age ranges, limiting generalizability across complexity and developmental stage. We compared academic, emotional-behavioral and social functioning at age 10, and predictors of outcomes, in a nonreferred cohort of children recruited at age 7, between those with full-syndrome (FS) ADHD and controls with no ADHD.

METHODS: This was a prospective cohort study with a 3-year follow-up period. Children were recruited from 43 socioeconomically diverse schools in Melbourne, Australia. Multi-informant outcomes at age 10 were academic functioning (Wide Range Achievement Test 4; Social Skills Improvement System), emotional-behavioral functioning (Strengths and Difficulties Questionnaire total), and social functioning (Strengths and Difficulties Questionnaire peer problems). Outcomes were compared across the groups by using adjusted random-effects linear regression analyses.

RESULTS: In total, 477 children (62% male) were recruited at a mean (SD) age of 7.3 years (0.4). There were 179 participants with FS ADHD, 86 with ST ADHD, and 212 controls. Sample retention was 78.2% at 3-year follow-up. Both the FS and ST groups were functioning worse than controls on almost all outcome measures. The best predictors of outcome for children with ADHD were working memory (academic outcome, $P < .001$), ADHD symptom severity (emotional-behavioral outcome, parent: $P < .001$; teacher: $P < .01$), and autism spectrum disorder symptoms (emotional-behavioral outcome, parent $P = .003$; social outcome, parent $P = .001$).

CONCLUSIONS: Children with FS and ST ADHD at age 7 experience persisting functional impairments across domains at age 10. The predictors identified at age 7 present potential targets for intervention to ameliorate impairments.



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Associate Professor Efron conceptualized and designed the study, drafted the initial manuscript, and reviewed and revised the manuscript; Associate Professor Sciberras conceptualized and designed the study, coordinated and supervised data collection, and critically reviewed the manuscript for important intellectual content; Professor Nicholson, Professor Anderson, Professor Hazell, Dr Ukoumunne, Associate Professor Silk, and Dr Jongeling conceptualized and designed the study and critically reviewed the manuscript for important intellectual content; Ms Gulenc contributed to the study design, data acquisition, analysis and interpretation, and revising the article critically; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

WHAT'S KNOWN ON THIS SUBJECT: Children with attention-deficit/hyperactivity disorder (ADHD) are at increased risk of negative academic, emotional-behavioral, and social outcomes. However, most ADHD cohort studies have involved clinical samples and have usually recruited children across wide age ranges, limiting developmentally sensitive evidence about predictors of outcomes.

WHAT THIS STUDY ADDS: Children with both full-syndrome and subthreshold ADHD demonstrated persistently poorer functioning than controls from ages 7 to 10. The key variables at age 7 that predicted poorer outcomes were ADHD symptom severity, working memory, and autism spectrum disorder symptoms.

To cite: Efron D, Nicholson JM, Anderson V, et al. ADHD at Age 7 and Functional Impairments at Age 10. *Pediatrics*. 2020;146(5):e20201061

Attention-deficit/hyperactivity disorder (ADHD) is associated with poorer functioning over time, including elevated risk of mental health problems and substance abuse, poorer social functioning,¹ and poorer educational achievement.² Predictors of variation in these outcomes include ADHD symptom severity, comorbidities, cognitive ability, family functioning, and household income.^{3,4} However, surprisingly little quality evidence exists regarding the factors that influence variability in ADHD symptoms and associated impairments over time despite the potential this offers to inform the development of preventive interventions. The need for longitudinal studies to better define the developmental course of ADHD has been highlighted in recent reviews.⁵

Much of what is known about the course of ADHD and its impact on functional outcomes has come from studies of samples of clinically referred children, which overrepresent boys, those taking medication, and children with more severe ADHD symptoms and comorbidities.^{6,7} Community-based ADHD cohort studies published to date have tended to be retrospective and/or lacked rigorous assessment of ADHD.^{8,9} Critically, baseline sampling in previous cohorts has typically spanned a wide age range, limiting the potential to detect age-sensitive determinants of later outcomes.

Recently, there has been growing interest in subthreshold (ST) ADHD, which includes individuals with symptoms who do not meet full diagnostic criteria. This group also demonstrates substantial functional impairments¹⁰; thus, efforts to identify who would benefit from early preventive interventions should be informed by evidence from cohort studies including both full-syndrome (FS) and ST groups.

We address these gaps in a prospective study of 36-month outcomes (age 10) for a community-ascertained sample of children ($N = 477$) with FS or ST ADHD and controls with no ADHD, classified at study entry at age 7.¹¹

Specifically, we aimed to do the following:

1. compare academic, emotional-behavioral, and social outcomes at 10 years between children in the FS ADHD, ST ADHD, and non-ADHD groups; and
2. examine modifiable baseline characteristics as potential predictors of age-10 academic, emotional-behavioral, and social outcomes across child (ADHD symptom severity, emotional symptoms, conduct problems, autism spectrum disorder [ASD] symptoms, working memory), parent (mental health, parenting hostility) and school (additional support) levels for children with ADHD (FS and ST combined).

METHODS

Design and Setting

In this study, we report on data from the Children's Attention Project, a community-based cohort study used to assess children with and without ADHD at 3 time points: baseline, 18 months, and 36 months (ages 7, 8.5, and 10 years, respectively).¹² Ethical approval was obtained from the human research ethics committees of The Royal Children's Hospital (31056) and the Victorian Department of Education and Training (2011_001095).

Eligibility and Procedures

Children were recruited from 43 government schools in Melbourne, Australia, representing diverse socioeconomic communities in 2011 and 2012. A two-stage procedure (screening followed by diagnostic interviewing) was used to ascertain

the sample. First, the Conners 3 ADHD Index¹³ was sent to the parents of all children in grade 1 (second year of school). For those children whose parents returned the survey and consented to teacher participation, the child's teacher was asked to also complete the Conners 3. Children were classified as screening positive for ADHD if both parent and teacher ratings on the ADHD Index were ≥ 75 th percentile for boys and ≥ 80 th percentile for girls.¹¹ A higher cut point was used for girls because our pilot data revealed that this resulted in better correspondence with diagnostic confirmation. Children with a previous ADHD diagnosis were also classified as positive screen results. Children were classified as screening negative if both their parent and teacher ADHD Index scores were < 75 th percentile for boys or < 80 th percentile for girls and there was no previous diagnosis of ADHD. Children with discordant parent and teacher ratings were not followed longitudinally in this study.

Next, all children who screened positive for ADHD were matched 1:1 by sex and school to a child who screened negative for ADHD, and all were invited to participate in the longitudinal study. Participation in the longitudinal study involved completion of National Institute of Mental Health Diagnostic Interview Schedule for Children Version IV (DISC-IV)¹⁴ with parents to confirm ADHD status and other mental health conditions, direct child assessments, and parent- and teacher-completed surveys. DISC-IV interviews were conducted by trained research assistants with at least a 4-year degree, blinded to baseline screening status. Children who screened positive and meet diagnostic criteria on the DISC-IV were classified as FS; those who screened positive but did not meet diagnostic criteria on the DISC-IV were classified as ST; and those who screened negative and did

not meet diagnostic criteria were classified as controls. The flow of participants into groups is shown in Fig 1.

Exclusion Criteria

Children were excluded if they had an intellectual disability, severe medical condition, genetic disorder, moderate-severe sensory impairment, or neurologic disorder. Families who were unable to complete the surveys and interviews in English were also excluded.

Follow-up

Parent and teacher surveys, diagnostic interviews, and direct child assessments were repeated 36 months postrecruitment (2014 and 2015) when the children were 10 years old.

Measures Outcomes at Age 10

Academic achievement was assessed directly and by teacher ratings. The Wide Range Achievement Test 4 (WRAT 4)¹⁵ word reading (word decoding and recognition) and math computation (counting, number identification, oral problem-solving, and written problem calculation) subtests were used for direct assessment. Standard scores based on age are reported (normative mean = 100; SD = 15) and a composite score was derived (average of the 2 subscales) for use in the predictive analyses. We also collected teacher-reported academic competence (7 items) from the Social Skills Improvement System (SSIS)¹⁶ (age-based standard scores, mean = 100; SD = 15). Emotional-behavioral and social outcomes were measured by using parent- and teacher-completed Strengths and Difficulties

Questionnaire (SDQ).¹⁷ Emotional-behavioral problems were measured by using the 20-item SDQ total problems score (range 0–40) summed from the emotional problems, conduct problems, inattention-hyperactivity and peer problems subscales. The 5-item peer problems subscale was also examined separately as our measure of social outcomes (range 0–10).

Predictors at Age 7

Child

ADHD symptom severity was measured by using the parent-reported Conners 3 ADHD Index.¹³ Working memory was measured by using the Digits Backward from the Wechsler Intelligence Scale for Children, Fourth Edition (scaled score).¹⁸ Emotional-behavioral and peer problems were measured by using the parent-reported SDQ. ASD symptoms were measured by using the 40-item, parent-report Social Communication Questionnaire Lifetime Form.¹⁹ Child receipt of additional assistance at school (receives specialized services or has an individual learning plan) was reported by teachers at age 7 years.

Parent

Primary caregiver mental health difficulties were measured by using the 6-item Kessler Psychological Distress Scale.²⁰ Parenting hostility was measured by using the 5-item parenting anger scale from the Longitudinal Study of Australian Children.²¹

Sample Characteristics

Child characteristics reported at both age 7 and age 10 include age, sex, cognitive function matrix reasoning subtest from the Wechsler Abbreviated Scale of Intelligence²²), parent and teacher-reported ADHD symptom severity (Conners 3 ADHD Index), parent-reported ASD symptoms (Social Communication Questionnaire), and parent-reported

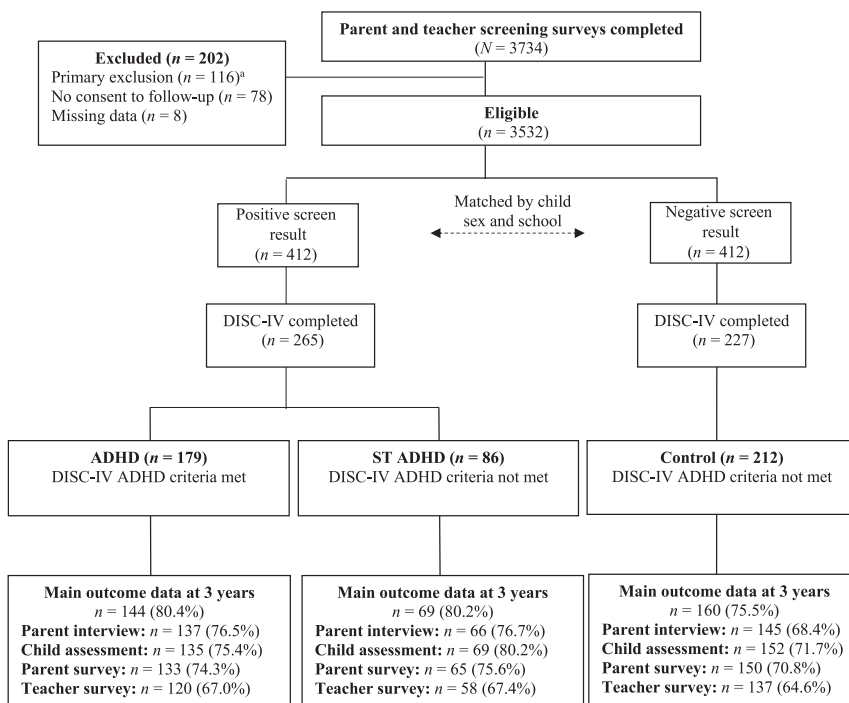


FIGURE 1 Recruitment flowchart. ^a Primary exclusion if the child had an intellectual disability, serious medical condition, genetic disorder, moderate-severe sensory impairment, or neurologic problem or the primary caregiver had insufficient English to complete assessments. ^b Defined as having data available on at least 1 of the parent interviews, child assessments, parent surveys, or teacher surveys available at the 3-year follow-up.

ADHD medication use. Mental health disorders including ADHD were assessed by using the DISC-IV.¹⁴ Children were classified as having an internalizing disorder if they met criteria for separation anxiety disorder, social phobia, generalized anxiety disorder, posttraumatic stress disorder, obsessive-compulsive disorder, major depression, hypomania, or manic episode and an externalizing disorder if they met criteria for oppositional defiant disorder or conduct disorder. The DISC-IV is used to report ADHD subtype and persistence at age 10. Primary caregiver characteristics reported at both age 7 and age 10 included single-parent status and education level, neighborhood socioeconomic disadvantage (residential postcode classification),²³ and parent mental health (6-item Kessler Psychological Distress Scale).

Statistical Analysis

Summary statistics were used to describe the continuous and categorical sample characteristics. Random-effects linear regression models were fitted to compare academic, behavioral-emotional, and social outcomes at 10 years between children with FS ADHD and controls without ADHD, between children with ST ADHD and controls without ADHD, and between children with FS ADHD and children with ST ADHD (aim 1). The random-effects regression analyses allowed for clustering at the school level. Both unadjusted analyses and analyses that adjusted for potential confounders identified a priori (child age, child sex, single-parent status, parent education level, and socioeconomic disadvantage) are reported. All continuous predictors and outcomes were standardized (mean = 0; SD = 1).

For aim 2, the FS and ST ADHD groups were combined to form a single ADHD group. Random-effects linear regression models were fitted to identify the age-7 predictors of

academic, emotional-behavioral, and social outcomes at age 10 for each of the ADHD and control groups (aim 2). We examined predictors of outcome in the control group to contextualize any relationships found for the ADHD group. For each outcome, simple (crude) models in which 1 predictor was used at a time and a single multivariable model including all potential predictors were fitted. The results from the multivariable analyses are considered primary.

All analyses were conducted for families with complete data (nonimputed) and then repeated by using imputation to account for missing data. Data were imputed by using the chained equations method. Forty complete data sets were imputed, which included all 477 children enrolled in the cohort study. Given the similarity in our findings in our complete case and imputed analyses, we focus on the imputed analyses as our primary analyses. All age-7 and age-10 variables included in our analyses were incorporated into our multiple imputation model.

All statistical analyses were conducted in Stata 15.0 (Stata Corp, College Station, TX).

RESULTS

Sample retention by outcome source is illustrated in the participant flowchart (Fig 1), with 78.2% ($n = 373$) of the baseline sample ($N = 477$) retained at age 10 years. Retention was defined as having data available on at least 1 key outcome variable. There were no marked differences between responders and nonresponders at age 10 by sex, ADHD symptom severity, ADHD subtype, presence of comorbidities, or primary caregiver high school completion rates (all measured at age 7).

Participant characteristics are described in Table 1. Two-thirds (66.4%) of children in the FS group, 25.8% in the ST group, and 2.8% of

controls met full ADHD criteria at age 10. The percentage taking ADHD medication increased from 12.6% at baseline to 21.4% at follow-up in the FS group and from 0% to 6.5% in the ST group. At follow-up, comorbid internalizing disorders were present in 26.4% and 16.7% of the FS and ST groups, respectively, and externalizing disorders were present in 51.2% and 24.3% of the FS and ST groups. The FS and ST groups were socially disadvantaged relative to the controls at baseline (primary caregiver education level and single-parent household status).

Outcomes at 10 Years in Children in the FS ADHD, ST ADHD, and Non-ADHD Groups (Aim 1)

Academic, emotional-behavioral, and social outcomes at age 10 were compared among the 3 groups (in pairs; Fig 2, Supplemental Tables 5 and 6). At age 10, with 1 exception (teacher-rated social problems, ST group), children in both the FS and ST groups had more difficulties than those in the control group across all outcome variables after adjustments. The FS group had higher parent-reported emotional-behavioral difficulties compared with the ST group but were similar on all other measures. This pattern was similar to that seen at age 7 (Supplemental Table 5).

Predictors of Age 10 Outcomes (Aim 2)

Academic Function

The best predictor of academic achievement (reading and math composite) in both the combined (FS and ST) ADHD group and the control group was working memory (Table 2). Emotional problems, conduct problems, and ASD symptoms predicted academic function in the ADHD group in the unadjusted analysis but not in the adjusted analysis.

TABLE 1 Sample Characteristics

	Age 7 y			Age 10 y		
	Control	ST ADHD	FS ADHD	Control	ST ADHD	FS ADHD
	<i>n</i> = 212	<i>n</i> = 86	<i>n</i> = 179	<i>n</i> = 137–152 ^a	<i>n</i> = 58–67 ^a	<i>n</i> = 120–140 ^a
Child						
Age in y, mean (SD)	7.3 (0.4)	7.4 (0.5)	7.3 (0.5)	10.4 (0.5)	10.5 (0.5)	10.5 (0.6)
Male sex, No. (%)	135 (63.7)	38 (44.2)	124 (69.3)	95 (62.5)	30 (44.8)	99 (70.7)
Cognitive function, matrix reasoning, mean (SD)	51.6 (10.3)	47.6 (9.4)	46.0 (9.7)	51.6 (8.1)	50.6 (10.9)	47.6 (11.2)
Diagnoses and symptoms						
ADHD symptom severity, parent report, mean (SD)	1.3 (1.9)	9.9 (3.7)	13.7 (4.0)	1.0 (2.1)	5.5 (5.6)	10.3 (6.4)
ADHD symptom severity, teacher report, mean (SD)	0.6 (1.6)	10.1 (5.9)	12.9 (5.4)	0.8 (2.5)	5.0 (5.9)	7.0 (6.4)
Met ADHD DISC-IV criteria, No. (%)	0 (0.0)	0 (0.0)	179 (100)	4 (2.8)	17 (25.8)	91 (66.4)
Combined	—	—	93 (52.0)	1 (25.0)	5 (29.4)	40 (43.5)
Inattentive	—	—	64 (35.8)	2 (50.0)	10 (58.8)	46 (50.0)
Hyperactive	—	—	22 (12.3)	1 (25.0)	2 (11.8)	6 (6.5)
Internalizing disorder, No. (%)	10 (4.7)	5 (5.8)	47 (26.3)	10 (7.0)	11 (16.7)	34 (26.4)
Externalizing disorder, No. (%)	17 (8.0)	21 (24.4)	97 (54.2)	13 (9.2)	16 (24.3)	66 (51.2)
ASD symptoms, mean (SD)	5.3 (4.0)	6.7 (5.7)	10.3 (7.2)	3.3 (2.8)	4.0 (3.2)	7.2 (5.8)
Medication use						
ADHD medications, No. (%)	0 (0.0)	0 (0.0)	21 (12.6)	0 (0.0)	4 (6.5)	27 (21.4)
Methylphenidate	0 (0.0)	0 (0.0)	21 (12.6)	0 (0.0)	3 (4.8)	25 (20.0)
Dexamphetamine	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Atomoxetine	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.67)	2 (1.67)
Parent and/or family						
Single-parent household, No. (%)	23 (11.4)	12 (15.4)	42 (25.2)	16 (11.4)	16 (25.8)	30 (24.4)
Primary caregiver educational level, <i>n</i> (%)						
Did not complete high school	37 (18.3)	19 (24.4)	62 (37.1)	22 (15.5)	16 (26.2)	31 (25.4)
Completed high school	70 (34.7)	27 (34.6)	64 (38.3)	45 (31.7)	18 (29.5)	48 (39.3)
Completed university	95 (47.0)	32 (41.0)	41 (24.6)	75 (52.8)	27 (44.3)	43 (35.3)
Primary caregiver psychological distress						
Symptoms, mean (SD)	2.6 (2.8)	3.8 (4.2)	5.3 (4.5)	2.6 (2.6)	4.2 (4.3)	5.3 (4.7)
Clinical cutoff, No. (%)	2 (1.0)	3 (3.9)	14 (8.4)	2 (1.4)	1 (1.6)	12 (9.8)
SEIFA, mean (SD)	1015.4 (45.3)	1029.2 (40.7)	1011.3 (43.2)	1016.1 (45.0)	1028.3 (45.0)	1012.7 (44.8)
School						
School support services, teacher report, No. (%)						
Received specialized services	17 (8.2)	26 (30.2)	61 (34.7)	5 (3.7)	9 (15.5)	39 (33.1)
Student support group	3 (1.5)	3 (3.5)	30 (17.0)	2 (1.5)	4 (6.9)	25 (21.4)

SEIFA, Socio-Economic Indexes for Areas. —, not applicable.

^a Ranges are used because of missing data at the 3-y follow-up.

Emotional-Behavioral Problems

In the ADHD group, ADHD symptom severity predicted both parent- and teacher-reported emotional-behavioral problems. Emotional problems, conduct problems, ASD symptoms, and parent mental health problems also predicted parent-reported emotional-behavioral problems in the ADHD group. In the control group, the only predictor of parent-reported emotional-behavioral problems was conduct problems; none of the variables examined were predictors of teacher-reported emotional-behavioral problems in the control group (Table 3).

Social Problems

In the ADHD group, although several variables predicted parent-reported social problems in the unadjusted analysis, ASD symptoms were the only variable for which there was evidence of a relationship in the adjusted model. No variables were associated with teacher-reported social problems in the ADHD group in the adjusted model. In the control group, no variables in the model predicted parent- or teacher-reported social problems (Table 4).

DISCUSSION

In this community-based longitudinal study of children recruited at age 7, children with both ST ADHD and FS ADHD were functioning worse on all outcomes (academic, emotional-behavioral, and social) at age 10 compared with controls, after controlling for demographic variables. The ST group had lower parent ratings on social and emotional problems than the FS group but was similarly impaired to the FS group across most outcome domains by teacher report. For the ADHD group (FS and ST combined) the strongest baseline predictors of



FIGURE 2

Forest plot revealing effect size differences in outcomes at 36 months between children with FS ADHD and controls, children with ST ADHD and controls, and children with FS ADHD and children with ST ADHD.

outcome at follow-up were working memory for academic functioning, ADHD symptom severity for emotional-behavioral problems, and ASD symptoms for social functioning. Emotional problems, conduct problems, ASD symptoms, and parent mental health symptoms at age 7 also predicted parent-reported emotional-behavioral problems at age 10 in children with ADHD.

The finding of persistently poorer academic performance highlights the importance of identifying academic difficulties in the early school years in children with ADHD and providing appropriate remedial interventions. Furthermore, our findings reveal the reliability of teacher ratings of academic competence in children with ADHD. Using this simple scale to classify children resulted in similar

findings to direct academic achievement testing. The practical implication is that in children with ADHD, academic delays can be identified by teachers and remedial supports provided without the need for formal assessment.

The ST group demonstrated functional status between the ADHD group and the controls at follow-up on all outcome measures. This is consistent with the findings from a Swedish longitudinal cohort twin study in which authors found a relationship between ADHD symptoms at age 9 to 12 and psychosocial problems at age 15 across ADHD, ST ADHD, and control groups.²⁴ Our findings for the ST group were also consistent with a cross-sectional Korean study of children aged 8 to 11 years, in which the ST group had parent ratings of academic function and emotional and behavioral symptoms in between those of FS ADHD and controls.²⁵ Consistent with our data, they found that ST ADHD had a more even sex ratio (56% boys) compared with cases of FS ADHD (83% boys). In neither of these studies did authors use direct child academic assessment or teacher-reported outcomes. Our findings extend this work by demonstrating differences in outcomes across settings for the ST

TABLE 2 Age 7 Variables Associated With Composite Academic Achievement (WRAT 4) at Age 10 (Imputed Analyses)

	ADHD ^a (n = 265)				Control (n = 212)			
	Unadjusted		Adjusted ^b		Unadjusted		Adjusted ^b	
	Standardized Coef (95% CI)	P	Standardized Coef (95% CI)	P	Standardized Coef (95% CI)	P	Standardized Coef (95% CI)	P
Child								
ADHD symptom severity	-0.001 (-0.2 to 0.2)	.99	0.1 (-0.1 to 0.2)	.48	0.2 (-0.3 to 0.6)	.48	0.4 (-0.1 to 0.8)	.11
Working memory	0.5 (0.3 to 0.6)	<.001	0.4 (-0.1 to 0.2)	<.001	0.3 (0.1 to 0.4)	<.001	0.4 (-0.1 to 0.4)	<.001
Emotional symptoms	-0.1 (-0.3 to -0.02)	.02	-0.1 (-0.2 to 0.05)	.26	-0.1 (-0.3 to 0.05)	.17	-0.1 (-0.2 to 0.1)	.53
Conduct problems	-0.2 (-0.3 to -0.04)	.01	-0.06 (-0.2 to 0.1)	.38	-0.2 (-0.4 to 0.02)	.08	-0.1 (-0.3 to 0.1)	.42
ASD symptoms	-0.2 (-0.3 to -0.1)	.001	-0.1 (-0.2 to 0.03)	.14	-0.1 (-0.3 to 0.1)	.59	0.02 (-0.2 to 0.2)	.84
Parent and family								
Mental health	-0.1 (-0.2 to 0.1)	.33	0.02 (-0.1 to 0.1)	.67	-0.1 (-0.2 to 0.1)	.48	0.01 (-0.2 to 0.2)	.91
Hostile parenting	-0.1 (-0.3 to -0.01)	.04	-0.1 (-0.2 to 0.1)	.23	-0.1 (-0.3 to 0.1)	.26	-0.04 (-0.3 to 0.2)	.69
School								
Additional assistance	-0.4 (-0.7 to -0.1)	.002	-0.2 (-0.4 to 0.05)	.12	-0.4 (-0.9 to 0.03)	.07	-0.5 (-1.0 to -0.01)	.05

CI, confidence interval; standardized coef, standardized regression coefficient.

^a ADHD group includes children with FS and ST ADHD.

^b Adjusted for all predictors and clustered at the school level.

TABLE 3 Age 7 Variables Associated With Parent- and Teacher-Reported Emotional-Behavioral Problems (Total Score SDQ) at Age 10 (Imputed Analyses)

	ADHD (<i>n</i> = 265)				Control (<i>n</i> = 212)			
	Unadjusted		Adjusted ^a		Unadjusted		Adjusted ^a	
	Standardized Coef (95% CI)	<i>P</i>	Standardized Coef (95% CI)	<i>P</i>	Standardized Coef (95% CI)	<i>P</i>	Standardized Coef (95% CI)	<i>P</i>
Parent-reported outcomes of emotional-behavioral problems								
Child								
ADHD symptom severity	0.5 (0.4 to 0.7)	<.001	0.3 (0.2 to 0.5)	<.001	0.3 (−0.1 to 0.6)	.12	0.04 (−0.3 to 0.4)	.81
Working memory	−0.1 (−0.2 to 0.04)	.24	−0.01 (−0.11 to 0.1)	.81	−0.1 (−0.2 to 0.04)	.27	−0.003 (−0.1 to 0.1)	.96
Emotional problems	0.3 (0.2 to 0.4)	<.001	0.1 (0.02 to 0.2)	.02	0.2 (0.1 to 0.4)	.001	0.1 (−0.04 to 0.2)	.15
Conduct problems	0.4 (0.3 to 0.5)	<.001	0.2 (0.1 to 0.3)	<.001	0.4 (0.2 to 0.6)	<.001	0.3 (0.1 to 0.6)	.001
ASD symptoms	0.3 (0.2 to 0.4)	<.001	0.1 (0.05 to 0.2)	.003	0.2 (0.04 to 0.4)	.02	0.1 (−0.04 to 0.3)	.13
Parent and family								
Mental health	0.2 (0.1 to 0.3)	<.001	0.1 (−0.0002 to 0.2)	.05	0.2 (0.1 to 0.4)	.002	0.1 (−0.04 to 0.3)	.13
Hostile parenting	0.3 (0.2 to 0.4)	<.001	0.05 (−0.1 to 0.2)	.42	0.2 (0.05 to 0.3)	.009	−0.1 (−0.2 to 0.1)	.48
School								
Additional assistance	0.2 (0.01 to 0.5)	.04	0.1 (−0.1 to 0.3)	.58	0.1 (−0.3 to 0.5)	.51	−0.004 (−0.4 to 0.4)	.98
Teacher-reported outcomes of emotional-behavioral problems								
Child								
ADHD symptom severity	0.3 (0.2 to 0.5)	<.001	0.2 (0.1 to 0.4)	.01	0.2 (−0.3 to 0.7)	.36	0.003 (−0.5 to 0.5)	.99
Working memory	−0.1 (−0.2 to 0.02)	.11	−0.1 (−0.2 to 0.04)	.17	0.004 (−0.1 to 0.2)	.96	0.05 (−0.14 to 0.2)	.56
Emotion problems	0.04 (−0.1 to 0.2)	.44	−0.05 (−0.2 to 0.1)	.38	0.1 (−0.1 to 0.3)	.17	0.04 (−0.2 to 0.2)	.68
Conduct problems	0.2 (0.1 to 0.3)	.004	0.1 (−0.1 to 0.2)	.38	0.2 (−0.01 to 0.5)	.06	0.2 (−0.1 to 0.5)	.26
ASD symptoms	0.1 (0.03 to 0.2)	.01	0.1 (−0.1 to 0.2)	.32	0.2 (−0.04 to 0.4)	.11	0.1 (−0.1 to 0.3)	.38
Parent and family								
Mental health	0.2 (0.1 to 0.3)	.001	0.1 (−0.01 to 0.2)	.07	0.2 (0.03 to 0.4)	.03	0.2 (−0.05 to 0.4)	.12
Hostile parenting	0.2 (0.1 to 0.3)	.001	0.1 (−0.04 to 0.3)	.17	0.2 (−0.02 to 0.3)	.08	−0.003 (−0.2 to 0.2)	.98
School								
Additional assistance	0.2 (−0.03 to 0.5)	.09	0.1 (−0.2 to 0.3)	.54	0.3 (−0.2 to 0.8)	.23	0.2 (−0.3 to 0.7)	.48

CI, confidence interval; standardized coef, standardized regression coefficient.

^a ADHD group includes children with FS and ST ADHD.

^b Adjusted for all predictors and clustered at the school level.

ADHD. We found that the ST group's teacher-reported social and emotional symptom profile and the teacher-reported academic competence were similar to the FS ADHD group. This suggests that children with ST ADHD need similar levels of classroom support as children with FS ADHD. Although lower than the FS group, the ST group had substantial rates of both internalizing and externalizing comorbid disorders, further highlighting the clinically important problems faced by these children. Furthermore, it was notable that although the rate of externalizing disorders was relatively constant between the two time points in both groups and the rate of internalizing disorders was relatively constant in the FS group, the rate of internalizing disorders in the ST group increased

substantially. This suggests that in the ST group, secondary emotional effects may accrue over time.

These findings extend our understanding of the critical relationship between working memory and academic functioning. Visuospatial working memory has been found to mediate the relationship between inattention and poorer math achievement one year later in early elementary schoolchildren generally.²⁶ Consistent with Reenie et al,²⁷ we found an association between working memory deficits and math achievement function longitudinally in children with ADHD. Authors of several intervention studies have investigated the effects of cognitive training primarily targeting working memory in children with ADHD.

Unfortunately, although performance on laboratory tests of working memory can be improved, there is little evidence of changes in ADHD symptoms or academic performance.²⁸ Training children to improve the neuropsychological deficits underpinning their functional difficulties²⁹ is conceptually attractive, but the clinical utility of this approach remains to be demonstrated. Perhaps combined approaches whereby working memory training occurs alongside academic remediation could be a fruitful approach in this population.

Our study demonstrates the critical influence of ASD symptoms on social and emotional functioning in children with ADHD. ASD symptoms have been found cross-sectionally to be associated with higher social and

TABLE 4 Age 7 Variables Associated With Parent- and Teacher-Reported Social Problems (Peer Problems SDQ) at Age 10 (Imputed Analyses)

	ADHD (<i>n</i> = 265) ^a				Control (<i>n</i> = 212)			
	Unadjusted		Adjusted ^b		Unadjusted		Adjusted ^b	
	Standardized Coef (95% CI)	<i>P</i>	Standardized Coef (95% CI)	<i>P</i>	Standardized Coef (95% CI)	<i>P</i>	Standardized Coef (95% CI)	<i>P</i>
Parent-reported outcomes of social problems								
Child								
ADHD symptom severity	0.4 (0.2 to 0.6)	<.001	0.2 (0.02 to 0.5)	.03	-0.1 (-0.5 to 0.3)	.67	-0.3 (-0.7 to 0.2)	.26
Working memory	-0.1 (-0.3 to 0.03)	.12	-0.1 (-0.2 to 0.1)	.41	-0.1 (-0.2 to 0.02) ^c	.1 ^c	-0.1 (-0.2 to 0.1)	.23
Emotional symptoms	0.1 (-0.01 to 0.2)	.07	0.005 (-0.1 to 0.1)	.94	0.1 (-0.1 to 0.2)	.47	-0.02 (-0.2 to 0.2)	.85
Conduct problems	0.2 (0.05 to 0.3)	.01	0.1 (-0.1 to 0.2)	.37	-0.2 (-0.06 to 0.4)	.16	0.2 (-0.06 to 0.5)	.14
ASD symptoms	0.3 (0.2 to 0.4)	<.001	0.2 (0.1 to 0.3)	.001	0.2 (-0.03 to 0.3)	.09	0.1 (-0.1 to 0.3)	.20
Parent and family								
Mental health	0.2 (0.04 to 0.3)	.01	0.1 (-0.05 to 0.2)	.21	-0.2 (-0.02 to 0.4)	.07	0.2 (-0.02 to 0.4)	.08
Hostile parenting	0.1 (0.003 to 0.3)	.05	0.005 (-0.2 to 0.2)	.96	0.003 (-0.2 to 0.2)	.97	-0.2 (-0.4 to 0.1)	.16
School								
Additional assistance	0.4 (0.1 to 0.7)	.002	0.2 (-0.1 to 0.5)	.12	0.2 (-0.3 to 0.7)	.42	0.1 (-0.36 to 0.6)	.65
Teacher-reported outcomes of social problems								
Child								
ADHD symptom severity	0.3 (0.1 to 0.5)	.007	0.2 (-0.03 to 0.4)	.09	0.1 (-0.4 to 0.6)	.67	-0.08 (-0.6 to 0.4)	.76
Working memory	-0.1 (-0.2 to 0.1)	.23	-0.1 (-0.2 to 0.1)	.48	0.01 (-0.1 to 0.2)	.88	0.1 (-0.1 to 0.2)	.54
Emotional symptoms	0.05 (-0.1 to 0.2)	.46	-0.02 (-0.2 to 0.1)	.77	0.1 (-0.04 to 0.3)	.14	0.1 (-0.1 to 0.3)	.51
Conduct problems	0.1 (-0.1 to 0.2)	.27	-0.02 (-0.2 to 0.2)	.77	0.1 (-0.1 to 0.4)	.29	0.1 (-0.2 to 0.4)	.70
ASD symptoms	0.1 (0.01 to 0.3)	.03	0.1 (-0.1 to 0.2)	.41	0.1 (-0.1 to 0.4)	.25	0.1 (-0.2 to 0.3)	.61
Parent and family								
Mental health	0.2 (0.1 to 0.3)	.004	0.1 (-0.01 to 0.3)	.06	0.3 (0.1 to 0.5)	.003	0.3 (0.04 to 0.5)	.02
Hostile parenting	0.1 (-0.02 to 0.3)	.08	0.04 (-0.1 to 0.2)	.62	0.1 (-0.1 to 0.3)	.15	-0.01 (-0.3 to 0.2)	.95
School								
Additional assistance	0.5 (0.1 to 0.8)	.01	0.2 (-0.1 to 0.5)	.22	0.3 (-0.2 to 0.8)	.28	0.2 (-0.4 to 0.8)	.48

CI, confidence interval; standardized coef, standardized regression coefficient.

^a ADHD group includes children with FS and ST ADHD.

^b Adjusted for all predictors and clustered at the school level.

^c Model does not account for school clustering as this failed to converge in imputed analyses.

emotional impairments in children with ADHD.³⁰ In the current study, we extend this by demonstrating that comorbid ASD impacts function over time in children with ADHD. A potential implication of this result is that early identification and treatment of elevated ASD symptoms may help reduce negative outcomes in children with ADHD. Our results suggest that a broad clinical approach is needed to manage ADHD, which includes not only ADHD symptom management but also identification and management of comorbid conditions such as ASD³¹ and internalizing and externalizing disorders.

This study had a number of design strengths. We recruited and carefully

phenotyped children within a narrow age band and retained three-quarters of the sample to follow-up. We sampled boys and girls across the sociodemographic spectrum and included children with all comorbidities, resulting in a real-life sample with mixed developmental vulnerabilities. We therefore believe our findings are generalizable to the population of children with ADHD in the community. Finally, we examined a broad range of functional outcomes, generating a rich understanding of the difficulties faced by these children and their families.

Our study also had some limitations. First, there were some potential sample biases on recruitment. Families

excluded because of incomplete screening data were relatively socially disadvantaged compared with participating families, and the rate of consent in our negative screening control group was lower than in our cases. Second, our design did not enable the examination of the influence of internalizing and externalizing disorders on outcomes at 10 years because we treated comorbidities as outcomes. This design was chosen to align with developmental pathways research regarding the sequence of emergence of mental health comorbidities.³² Third, the definition of ST differs between cohorts.³³ We believe ours is robust and clinically meaningful, but

the definition needs to be considered when comparing results with other studies. Finally, although we have reported previously on the prevalence and predictors of medication use in this cohort,³⁴ only a minority of participants had been treated with medications, so we were unable to comment on treatment effects.

CONCLUSIONS

ADHD symptoms in early elementary school are robust markers of developmental and mental health vulnerability. This is true irrespective of whether

children meet diagnostic criteria. Therefore, clinicians should monitor children with ADHD symptoms even when they fall below the diagnostic threshold. The strongest modifiable risk factors were poor working memory (academic outcome), ADHD symptom severity (emotional-behavioral), and ASD symptoms (emotional-behavioral and social). This information should help to inform the development of intervention models used to improve outcomes in ADHD.

ABBREVIATIONS

ADHD: attention-deficit/hyperactivity disorder
ASD: autism spectrum disorder
DISC-IV: Diagnostic Interview Schedule for Children Version IV
FS: full-syndrome
SDQ: Strengths and Difficulties Questionnaire
SSIS: Social Skills Improvement System
ST: subthreshold
WRAT 4: Wide Range Achievement Test 4

DOI: <https://doi.org/10.1542/peds.2020-1061>

Accepted for publication Aug 14, 2020

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PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

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FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: Funded by the Australian National Health and Medical Research Council (project grant 1008522). The funder of the study had no role in the study design, data collection, data analysis, data interpretation, or writing of the report nor in the decision to submit the article for publication. The corresponding author had full access to all the data and had final responsibility for the decision to submit for publication. Associate Professor Efron was supported by a Clinician Scientist Fellowship from the Murdoch Children's Research Institute. Murdoch Children's Research Institute is supported by the Victorian Government's Operational Infrastructure Support Program. Professor Nicholson was funded by the Roberta Holmes Chair for Contemporary Parenthood at La Trobe University. Professor Anderson was supported by a National Health and Medical Research Council Practitioner Fellowship. Dr Koumounne was supported by the National Institute for Health Research Applied Research Collaboration South West Peninsula. The views expressed are those of the author(s) and not necessarily those of the National Health Service, the National Institute for Health Research, or the Department of Health and Social Care. Associate Professor Sciberras was funded by a National Health and Medical Research Council Career Development Fellowship (1110688) and a veski Inspiring Women's Fellowship. The funder/sponsor did not participate in the work.

POTENTIAL CONFLICT OF INTEREST: Professor Hazell's employer has received payment from Shire for a speaker fee; the other authors have indicated they have no potential conflicts of interest to disclose.

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Pediatrics 2020;146;

DOI: 10.1542/peds.2020-1061 originally published online October 6, 2020;

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