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Literacy and Numeracy Underachievement in Boys and Girls With ADHD

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Abstract

Objective: The aim was to determine literacy and numeracy outcomes, among children with and without ADHD by gestational age and gender. **Method:** De-identified linked population data from the Western Australian Monitoring of Drugs of Dependence System and Western Australian Literacy and Numeracy Assessment databases, and the Midwives Notification System used information on 6,819 children with ADHD compared with 14,451 non-ADHD children. **Results:** A total of 23% of boys and 28% of girls with ADHD had numeracy scores below the benchmark in School Year 3, compared with 11% of children without ADHD. These differences were also evident for reading, writing, and spelling through primary school. Children with ADHD and reduced gestational age were at a greater risk of not meeting numeracy and reading benchmarks, compared with children born at term. **Conclusion:** Children with ADHD are disadvantaged from an early age in key areas of learning, and this risk increased with reduction in gestational age at birth. *(J. of Att. Dis. XXXX; XX(X) XX-XX)*

Keywords

ADHD, numeracy, literacy, reading, behavior, gestational age

Introduction

ADHD is one of the commonest mental health disorders in childhood with a prevalence of 5.3% (Polanczyk, de Lima, Horta, Biederman, & Rohde, 2007). The core symptoms of inattention, impulsivity, and hyperactivity (American Psychiatric Association [APA], 2000, 2013) affect academic functioning (Biederman et al., 1996; Loe & Feldman, 2007; Massetti et al., 2008; Rapport, Scanlan, & Denney, 1999; Sexton, Gelhorn, Bell, & Classi, 2012; Tannock, 1998). Comorbidities are common in children diagnosed with ADHD (Yoshimasu et al., 2012). A total of 30% to 50% can have learning difficulties (August & Garfinkel, 1990; Gillberg et al., 2004), including numeracy difficulties or dyscalculia in 11% (Monuteaux, Faraone, Herzig, Navsaria, & Biederman, 2005), and reading difficulty or dyslexia in 23% to 49% (Pennington, Willcutt, & Rhee, 2005; Sexton et al., 2012; Willcutt & Pennington, 2000; Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005). Fine motor difficulties resulting in written language disorders can occur in up to 60% of children with ADHD by 19 years of age compared with 12% in non-ADHD children (Langmaid, Papadopoulos, Johnson, Phillips, & Rinehart, 2014; Rosenblum, Epsztein, & Josman, 2008; Yoshimasu et al., 2011). These learning difficulties are often interrelated and affect fluency, word recognition, decoding, spelling, and putting thoughts onto paper, which individually or in combination can result in underachievement and a greater need for educational assistance (Butterworth & Kovas, 2013; Jensen et al., 2004).

Gender is an important variable to consider when evaluating core symptoms of ADHD (Gershon, 2002; Hasson & Fine, 2012), where ADHD is more commonly diagnosed among boys (Barkley, 2006; Biederman et al., 2002), who display more impulsive and disruptive behaviors, which are more likely to come to the attention of teachers. Symptom severity may reflect differing cognitive abilities between the sexes (Arnett, Pennington, Willcutt, DeFries, & Olson, 2014; Barkley, 2006; Biederman et al., 2002).

Studies on ADHD and learning difficulties have mostly focused on reading difficulties. These studies are also subject to limitations, including small community samples,

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household surveys, parent-reported ADHD symptoms, and psychiatric hospital samples (Biederman et al., 2002; Carroll, Maughan, Goodman, & Meltzer, 2005; Pastor & Reuben, 2008). One population birth cohort of 5,718 children was compared with 379 children with a research diagnosis of ADHD; a higher incidence of reading (Yoshimasu et al., 2010) and writing difficulties (Yoshimasu et al., 2011) was found in both genders in those children with ADHD. However, the risk of reading difficulties associated with ADHD was significantly higher in girls than in boys. In a case control study (ADHD = 280, non-ADHD = 242) on the influence of gender on ADHD, Biederman et al. (2002) found that girls with ADHD had fewer learning disorders (including mathematics and reading), compared with boys with ADHD. Information on numeracy difficulties associated with ADHD is lacking at the population level.

Despite the strong genetic association for learning disorders (Olson, 2002), ADHD (Franke, Neale, & Faraone, 2009), and combined disorders (Willcutt et al., 2010), environmental factors like maternal age, gestational age, and socioeconomic factors need to be considered. Recent reports have identified that children born very preterm (<32 weeks), moderately preterm (32-36 weeks), and even early term (37-38 weeks) have lower cognitive ability than their term counterparts (Boyle et al., 2012; Chyi, Lee, Hintz, Gould, & Sutcliffe, 2008; Lindstrom, Winbladh, Haglund, & Hjern, 2007; Malacova et al., 2008; van Baar, Vermaas, Knots, de Kleine, & Soons, 2009; Yang, Platt, & Kramer, 2010). Population studies have confirmed the small increased risk of ADHD associated with prematurity and also for early term births (Lindstrom, Lindblad, & Hjern, 2011; Silva, Colvin, Hagemann, & Bower, 2014).

There are no population studies looking simultaneously at gender differences related to numeracy and spelling for children with ADHD, and the effects of gestational age (including moderate preterm and early term) on literacy and numeracy difficulties in children with ADHD.

Our hypothesis is that children with ADHD, irrespective of gender, are significantly educationally disadvantaged especially if born early. Our aim was to determine educational outcomes in numeracy and literacy experienced by boys and girls with ADHD at a population level and the effect of gestational age.

Method

For this study, data were extracted from three state-wide databases: the Monitoring of Drugs of Dependence System (MODDS) database, the Midwives Notification System, and the Western Australian (WA) Literacy and Numeracy Assessment (WALNA). Using these linked data, we looked at three cross-sectional birth cohorts in School Years 3, 5, and 7.

The WA Stimulant Regulatory Scheme commenced in August 2003 following a parliamentary inquiry on the increased prescribing of stimulant medication (SM) for treatment of ADHD. MODDS was set up in August 2003 to monitor SM being dispensed in Western Australia. For our study, we extracted data on all children and young adults born from January 1, 1980, and who were below 25 years of age, who met the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM-IV*; APA, 1994)/ International Statistical Classification of Diseases and Related Health Problems (10th Revision; ICD-10) criteria for ADHD diagnosed by a pediatrician or psychiatrist, and were dispensed SM between August 2003 and December 2007 in Western Australia. We restricted our sample to non-Aboriginal children born in Western Australia between 1989 and 1996 (n = 6,819). Records of children identified with ADHD were linked to the Midwives Notification System, a statutory collection of pregnancy, birth, and neonatal information completed by midwives for all births with >20 weeks gestation in Western Australia since 1980 (Gee, 1994). Records for Aboriginal children were excluded as ADHD may be underestimated due to possible reduced access to treatment (Morgan, Staff, Hillemeier, Farkas, & Maczuga, 2013).

From the Midwives Notification System, we obtained demographic information on gender, maternal marital status, and maternal age at birth of the child (below 20 years, 20-30 years, and above 30 years) and gestation. We stratified gestational age as less than 37 weeks and 37 weeks or more. For our final analysis of looking at the independent effect of gestational age for moderate and early term infants, we further stratified gestational age as early preterm (<32 weeks), moderate preterm (32-36 weeks), early term (37-38 weeks), and term 39+ weeks.

Our reference group consisted of a random sample of records taken from the Midwives Notification System, that were not linked to the WA Stimulant Regulatory Scheme, and were frequency matched 2:1 by year of birth, gender, and socioeconomic status to the case group (n = 14,451). Socioeconomic status was assessed using the Socio-Economic Indexes for Areas (SEIFA), which provides a measure of relative socioeconomic status about the area in which the child was born (Australian Bureau of Statistics, 2001).

Outcome Measures

The education outcome measures used were from the WALNA testing results introduced to Year 3 students in 1999, Years 3 and 5 students in 2000, and Years 3, 5, and 7 in 2001. It continued until 2007 when it was replaced by the National Assessment Program–Literacy and Numeracy. WALNA was a curriculum-based testing system developed in keeping with standards of best psychometric practice and annually evaluated content, construct validity, precision, and bias, with an internal reliability of .8. The numeracy test consisted of multiple-choice, short- and open-response questions. Year 5 and Year 7 students used calculators for part of the assessment tasks. Teachers were allowed to provide some assistance on unfamiliar words, but mathematical concepts were not explained. The reading test assessed the child's ability to read effectively using multiple-choice, short- and open-response questions. Spelling was assessed through students' writing and through two other tasks—spelling in context and a spelling correction task. The writing test was a narrative using a short story, fable, or anecdote (Independent Schools, 2007). The results were scored in relation to meeting the national benchmarks that are agreed standards of performance that professional educators throughout Australia consider represent the minimum levels required for Year 3, Year 5, and Year 7 students to make adequate progress in their schooling (Independent Schools, 2007; http://www.det.wa.edu.au/education/walna/).

The students not meeting the benchmarks were students who participated in the testing and did not meet the State benchmark standard for that year of testing. Students who were recorded as did not sit the test included students with disabilities from education support centers, students with English as a second language who had been at school for less than 12 months and did not sit the tests, and students who were absent for testing due to accident, illness, or non-attendance for other reasons. Children were exempt from taking the test if they were intellectually impaired, lacked competency in English when it was not their first language, and in other special circumstances. Having a diagnosis of ADHD was not a reason for exemption.

Data Linkage

Data linkage and extraction were performed by staff at the WA Data Linkage Branch that sits within the WA Department of Health. The Data Linkage Branch uses best practice protocol for linkage, ensuring strict privacy-preserving practices (Holman et al., 2008). The WA Data Linkage Branch uses the Automatch software package with probabilistic matching based on medical record number, surname, first given name and initial, date of birth, sex, and address as the principal matching fields. Missed links have been estimated at 0.11% (Holman, Bass, Rouse, & Hobbs, 1999). The WA Data Linkage System, through which this study has obtained current data, has been validated (Holman et al., 1999) and used extensively for health research (Holman et al., 2008). The datasets used for the current study are State government data collections, created as a statutory requirement and used for administrative purposes. It is likely that the data are complete and accurate. All records for this study were also validated internally. For example, sex and dates of birth or death were checked across each source.

The data on cases of ADHD and the reference group were linked to their WALNA scores. Educational results were obtained for three cross-sectional groups: For Year 3 testing (age 7-8 years old), we identified children born between 1991 and 1996; for Year 5 testing (age 9-10 years old), we identified children born between 1989 and 1995; and for Year 7 testing (age 11-12 years old), we identified children born between 1989 and 1993. The study design is illustrated in Figure 1.

Medication Prescribed

We wanted to determine the percentage of children diagnosed with ADHD, who were dispensed SM over the testing period. However, we had overlapping data for only 2 years on SM dispensed and WALNA testing results (2004-2005) for children diagnosed and treated for ADHD. The SM used in WA is predominantly methylphenidate short acting (100 tablets per prescription), methylphenidate extended release (30 capsules per prescription), and dexamphetamine (100 tablets per prescription). The median age of children prescribed medication on the MODDS database is 12 years (Department of Health, 2010). A minimum dose the children are likely to take is one extended release methylphenidate daily (script required every 30 days), or two dexamphetamine or methylphenidate short acting daily (script required every 60 days or less). With the WALNA testing dates available for this study, we were able to compare SM dispensed for boys within 90 days of the WALNA testing with those dispensed over 90 days. Some children may have only commenced SM after the testing date.

Analysis

For children with and without ADHD, we calculated the odds ratios (ORs) and 95% confidence intervals (CIs) for not reaching the benchmark for numeracy, reading, writing, and spelling in their primary Schooling Years 3, 5 and 7. We used logistic regression analysis to calculate the OR and 95% CI, adjusting for year of birth, sex, SEIFA, maternal age, and gestational age.

We used SAS/STAT software, Version 9.3, of the SAS System for Windows for data analyses (SAS/STAT, 2002-2010).

Results

The variables used for children taking the Year 3, 5, and 7 WALNA test who were diagnosed with ADHD and dispensed SM between 2003 and 2007 are shown in Table 1. There was little difference between the ADHD and non-ADHD groups apart from the increase in single marital status in the ADHD group.

Both girls and boys with ADHD were significantly less likely to reach the minimum benchmark scores for numeracy, reading, spelling, and writing in each of the testing

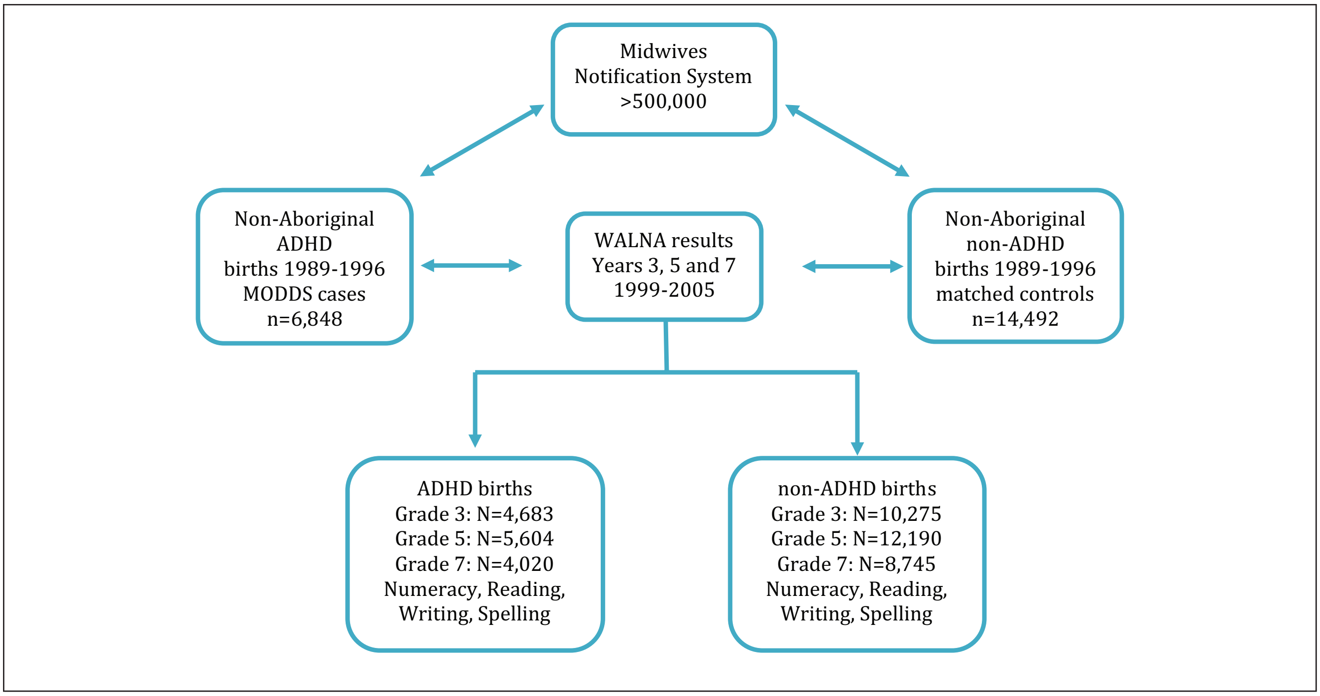

Figure 1. Study methodology flowchart.
Note. MODDS = Monitoring of Drugs of Dependence System; WALNA = Western Australian Literacy and Numeracy Assessment.

Table 1. Study Demography for ADHD and Non-ADHD Children.

	ADHD children (n = 6,819)		Non-ADHD children (n = 14,451)	
Variables	n	%	n	%
Sex—Male	5,471	80	11,478	78
Maternal age (years)				
<20	515	8	685	5
20-30	3,840	56	8,014	56
30-40	2,366	35	5,521	38
>40	95	1	231	2
Marital status single	964	14	1,321	9
Birth weight <2,500 g	457	7	712	5
Gestational age (week)				
<33	138	2	165	1
33-36	470	7	858	6
37-38	1,895	28	3,686	26
≥39	4,316	63	9,742	67
SEIFA				
<25%	1,976	32	3,742	27
25%-50%	1,614	26	3,855	28
50%-75%	1,351	22	3,278	24
>75%	1,204	20	2,784	20
Missing	674		792	
Year of birth				
1988-1993	4,401	65	9,348	65
1994-2000	2,418	35	5,103	35

Note. SEIFA = Socio-Economic Index of Disadvantage for Areas.

years (Table 2), compared with their non-ADHD peers. A total of 23% of boys and 28% of girls with ADHD had numeracy scores below the benchmark in Year 3, compared with 11% of children without ADHD, and these proportions remained elevated and changed little in Years 5 and 7. Boys with ADHD were 2.4 times (OR = 2.41; 95% CI = [2.16, 2.69]) and girls with ADHD nearly 3 times (OR = 2.97; 95% CI = [2.39, 3.68]) more likely to fail to meet the Year 3 numeracy benchmark compared with children without ADHD. Boys with ADHD were less likely not to reach Year 3 (OR = 0.80; 95% CI = [0.67, 0.96]), 5 (OR = 0.62; 95% CI = [0.53, 0.73]), and Year 7 (OR = 0.75; 95% CI = [0.63, 0.90]) numeracy benchmark compared with ADHD girls. In total, 15% of boys and girls with ADHD had reading scores below the benchmark in Year 3 compared with 7% of boys and 5% of girls without ADHD. This proportion increased through primary school for boys and girls with ADHD. For spelling, more than one third of children with ADHD did not reach the State benchmark throughout their primary schooling. In fact, girls with ADHD were 5 times (OR = 5.23; 95% CI = [4.14, 6.62]) more likely not to reach benchmark scores in spelling in Year 3, and boys with ADHD were nearly 3 times (OR = 2.80; 95% CI = [2.54, 3.08]) more likely not to reach the benchmark in Year 3 compared with their non-ADHD reference groups. These differences remained through primary school. For writing, 28% of boys and 24% of girls with ADHD failed to reach benchmark by Year 3 where boys with ADHD were 3 times (OR = 3.17; 95% CI = [2.84, 3.53]) more likely and girls 5 times (OR = 5.48; 95% CI = [4.18, 7.20]) more likely not to reach benchmark scores for writing compared with their non-ADHD counterparts. By Year 7, the proportions of boys and girls (with and without ADHD) not reaching the writing benchmark was smaller than in Years 3 and 5, but the OR remained high for both boys and girls with ADHD compared with their non-ADHD peers. Boys with ADHD were over twice more likely not to reach Year 7 writing benchmark scores compared with ADHD girls (OR = 2.23; 95% CI = [1.73, 2.87]). Fewer than 5% of children were absent at each testing year although the proportion was slightly higher for ADHD children.

For each gestational age bracket, we found an increased risk of ADHD children not reaching the benchmark for testing in numeracy, reading, spelling, and writing at all three testing times, compared with term births (see Table 3). Around one third of moderately (33-36 weeks) preterm boys and girls with ADHD did not reach the minimum numeracy benchmark at the third, fifth, or seventh primary school year. Numeracy failure also extended to children with ADHD born at early term where boys and girls by Year 7 had a 10% (OR = 1.10; 95% CI = [0.99, 1.22]) and 26% (OR = 1.26; 95% CI = [1.02, 1.55]) increased risk, respectively, of not reaching the benchmark compared with their term counterparts. Lower gestational age was also associated with an increased risk of boys and girls with ADHD not reaching the State benchmark in reading, spelling, and writing at each testing time. Even ADHD children born at early term (37-38 weeks) were at risk of literacy failure, irrespective of gender, compared with their term counterparts.

Table 4 compares only boys with ADHD who were dispensed a SM prescription within 90 days of the WALNA testing compared with boys who were dispensed a SM prescription over 90 days prior to the testing (girls were not included in this table due to small sample size). Only 7% of children in Year 3 (33/474), 5% of children in Year 5 (56/1,075), and 5% of children in Year 7 (52/1,128) diagnosed with ADHD had been dispensed a SM prescription 90 days before the testing date. On comparing those who had a script dispensed less than 90 days with those who either had a script dispensed over 90 days before the testing, or after the test date, the trends for reading and writing scores were better for boys who had been dispensed SM <90 days before testing, although numbers were small and not likely to be significant. There was a little difference in the percentage of boys who did not reach the benchmark for numeracy and spelling in either group.

Discussion

This population study of children diagnosed with ADHD using strict diagnostic criteria (*DSM-IV*/ICD-10) and treated with SM has shown that about a quarter of both boys and girls with ADHD did not reach the State benchmark testing for numeracy, writing, and spelling over their primary school years. Children with ADHD also had an increased risk of numeracy and literacy failure associated with reducing gestational age even for moderately preterm and early term deliveries.

Yoshimasu et al. (2010) found an association between ADHD and reading difficulties, irrespective of gender, where both boys and girls with ADHD had a similar disadvantage. They also found that non-ADHD boys had a higher risk of reading difficulties compared with non-ADHD girls, where the difference between ADHD and non-ADHD girls was greater due to better reading skills among non-ADHD girls (Yoshimasu et al., 2010). Our study confirmed the strong association between ADHD and reading difficulties, where by Year 7, nearly one quarter of boys and girls with ADHD did not reach the minimum standards for reading. Boys with ADHD were twice as likely to be disadvantaged, and girls with ADHD were more than 3½ times as disadvantaged than their non-ADHD peers, although for reading there were little gender differences between children with ADHD. This study highlights the need for the ongoing monitoring of reading skills and the provision of extra support to children diagnosed with ADHD throughout their primary school years (Kronenberger & Dunn, 2003; Yoshimasu et al., 2011).

Table 2. Children Who Did Not Meet the Benchmark by Gender and School Year.

	Male					Female					
	ADHD		Non-ADHD			ADHD		Non-ADHD			
	n	(%)	*n*	(%)	Adjusted[a] OR (95% CI)	*n*	(%)	*n*	(%)	Adjusted[a] OR (95% CI)	OR for ADHD male vs. ADHD female (95% CI)
Year 3	3,787		8,206			896		2,069			
Numeracy	844	(24)	875	(11)	2.41 [2.16, 2.69]	243	(28)	215	(11)	2.97 [2.39, 3.68]	0.80 [0.67, 0.96]
Reading	533	(15)	522	(7)	2.46 [2.15, 2.82]	125	(15)	97	(5)	3.10 [2.31, 4.16]	1.09 [0.87, 1.37]
Spelling	1,273	(36)	1,270	(16)	2.80 [2.54, 3.08]	263	(31)	148	(8)	5.23 [4.14, 6.62]	1.27 [1.07, 1.51]
Writing	982	(28)	825	(10)	3.17 [2.84, 3.53]	199	(24)	96	(5)	5.48 [4.18, 7.20]	1.27 [1.06, 1.53]
Year 5	4,484		9,659			1,120		2,531			
Numeracy	1,024	(24)	1,074	(11)	2.38 [2.15, 2.64]	359	(34)	264	(11)	3.95 [3.26, 4.78]	0.62 [0.53, 0.73]
Reading	801	(19)	914	(7)	2.05 [1.84, 2.28]	184	(17)	129	(5)	3.56 [2.77, 4.57]	1.11 [0.92, 1.33]
Spelling	1,605	(38)	1,745	(20)	2.59 [2.37, 2.82]	337	(32)	220	(9)	4.64 [3.80, 5.66]	1.27 [1.09, 1.48]
Writing	1,499	(36)	1,585	(18)	2.66 [2.43, 2.91]	273	(26)	184	(8)	4.00 [3.23, 4.96]	1.60 [1.36, 1.88]
Year 7	3,229		6,908			791		1,837			
Numeracy	867	(28)	946	(12)	2.31 [2.06, 2.57]	256	(33)	250	(14)	2.98 [2.41, 3.68]	0.75 [0.63, 0.90]
Reading	748	(24)	847	(12)	2.17 [1.93, 2.44]	166	(22)	128	(7)	3.45 [2.65, 4.48]	1.16 [0.95, 1.42]
Spelling	1,328	(42)	1,574	(23)	2.36 [2.14, 2.60]	291	(38)	239	(13)	3.90 [3.16, 4.83]	1.21 [1.02, 1.44]
Writing	686	(22)	642	(8)	2.57 [2.27, 2.91]	83	(11)	67	(4)	3.02 [2.14, 4.27]	2.23 [1.73, 2.87]

Note. OD = odds ratio; CI = confidence interval.
[a]Adjusted for maternal age, socioeconomic status, year of birth, and prematurity.

Table 3. Percentages and Odds Ratios of ADHD and Non-ADHD Children Who Did Not Meet the Numeracy and Literacy Benchmark by Gestational Age.

	Year 3		Year 5		Year 7	
	% ADHD vs. % non-ADHD		% ADHD vs. % non-ADHD		% ADHD vs. % non-ADHD	
	OR (95% CI)[a]		OR (95% CI)[a]		OR (95% CI)[a]	
	Male	Female	Male	Female	Male	Female
Numeracy						
<33 weeks	32 vs. 19	47 vs. 29	34 vs. 19	64 vs. 21	39 vs. 21	46 vs. 27
	1.92 [1.38, 2.68]	1.81 [0.92, 3.58]	1.78 [1.30, 2.42]	1.30 [0.69, 2.43]	1.45 [1.00, 2.11]	1.32 [0.63, 2.78]
33-36 weeks	32 vs. 9	35 vs. 10	34 vs. 14	36 vs. 16	33 vs. 13	36 vs. 14
	1.21 [1.02, 1.43]	1.24 [0.85, 1.79]	1.09 [0.93, 1.28]	1.05 [0.74, 1.48]	1.12 [0.93, 1.35]	1.11 [0.75, 1.65]
37-38 weeks	22 vs. 12	24 vs. 12	23 vs. 12	34 vs. 10	26 vs. 15	36 vs. 13
	1.16 [1.05, 1.28]	1.26 [1.04, 1.53]	1.08 [0.99, 1.18]	1.23 [1.03, 1.48]	1.10 [0.99, 1.22]	1.26 [1.02, 1.55]
≥39 weeks	23 vs. 11	29 vs. 11	23 vs. 11	32 vs. 11	27 vs. 13	31 vs. 14
	1	1	1	1	1	1
Reading						
<33 weeks	9 vs. 11	21 vs. 14	18.9 vs. 13.1	24 vs. 17	15 vs. 19	46 vs. 5
	2.18 [1.58, 3.03]	1.91 [0.98, 3.73]	1.95 [1.43, 2.64]	1.39 [0.75, 2.58]	1.60 [1.10, 2.33]	1.43 [0.67, 3.02]
33-36 weeks	20 vs. 8	10 vs. 5	20.6 vs. 9.1	21 vs. 10	27 vs. 13	22 vs. 7
	1.17 [0.99, 1.39]	1.16 [0.80, 1.69]	1.17 [1.00, 1.38]	1.12 [0.80, 1.57]	1.18 [0.98, 1.41]	1.16 [0.78, 1.71]
37-38 weeks	15 vs. 7	15 vs. 4	18.7 vs. 10.1	21 vs. 6	25 vs. 12	23 vs. 8
	1.15 [1.04, 1.26]	1.26 [1.03, 1.53]	1.11 [1.01, 1.21]	1.21 [1.01, 1.44]	1.11 [1.00, 1.23]	1.23 [1.00, 1.51]
≥39 weeks	15 vs. 7	15 vs. 5	18.8 vs. 9.9	15 vs. 5	23 vs. 13	20 vs. 7
	1	1	1	1	1	1
Spelling						
<33 weeks	37.0 vs. 18.6	31.6 vs. 33.3	38.6 vs. 19.8	33.3 vs. 16.7	36.2 vs. 28.0	50.0 vs. 22.7
	1.90 [1.36, 2.66]	1.60 [0.79, 3.27]	1.93 [1.41, 2.64]	1.48 [0.79, 2.79]	1.55 [1.06, 2.26]	1.49 [0.71, 3.11)
33-36 weeks	41.8 vs. 19.2	50.0 vs. 10.5	43.0 vs. 19.4	35.0 vs. 12.6	50.7 vs. 24.1	40.4 vs. 17.2
	1.17 [0.99, 1.39]	1.02 [0.69, 1.50]	1.12 [0.95, 1.31]	1.06 [0.75, 1.51]	1.12 [0.92, 1.35]	1.12 [0.76, 1.66]
37-38 weeks	35.5 vs. 17.2	31.7 vs. 6.8	37.4 vs. 19.0	34.7 vs. 8.8	41.0 vs. 22.5	40.6 vs. 11.3
	1.13 [1.02, 1.24]	1.24 [1.01, 1.51]	1.08 [0.99, 1.19]	1.21 [1.01, 1.45]	1.14 [1.02, 1.26]	1.25 [1.01, 1.54)
≥39 weeks	35.2 vs. 15.7	28.9 vs. 7.3	37.7 vs. 19.0	30.5 vs. 9.0	42.3 vs. 23.4	35.7 vs. 13.5
	1	1	1	1	1	1
Writing						
<33 weeks	30.8 vs. 19.3	21.1 vs. 15	34.4 vs. 29.5	27.3 vs. 6.9	15.4 vs. 12.2	
	2.08 [1.49, 2.89]	2.08 [1.03, 4.20]	1.94 [1.42, 2.66]	1.72 [0.93, 3.18]	1.55 [1.06, 2.27]	
33-36 weeks	32.4 vs. 11.7	34.6 vs. 8.7	39.8 vs. 19.4	29.0 vs. 15.2	25.5 vs. 9.8	19.6 vs. 11.3
	1.20 [1.01, 1.43]	1.09 [0.74, 1.60]	1.13 [0.97, 1.33]	1.07 [0.76, 1.51]	1.13 [0.93, 1.36]	1.08 [0.73, 1.60]
37-38 weeks	27.3 vs. 10.4	28.1 vs. 4.9	35.3 vs. 16.6	29.2 vs. 6.1	21.5 vs. 9.4	11.8 vs. 3.4
	1.14 [1.03, 1.26]	1.20 [0.98, 1.47]	1.10 [1.00, 1.20]	1.23 [1.03, 1.47]	1.12 [1.01, 1.25]	1.27 [1.04, 1.57)
≥39 weeks	27.7 vs. 10.6	20.8 vs. 4.6	36.0 vs. 16.3	23.9 vs. 7.8	22.5 vs. 9.5	10.0 vs. 3.2
	1	1	1	1	1	1

Note. OD = odds ratio; CI = confidence interval.
[a]Adjusted for maternal age, socioeconomic status, and year of birth.

Table 4. Percentage of Boys With ADHD Who Did Not Meet the Numeracy and Literacy Benchmark and SM Dispensed.

	SM dispensed <90 days		SM not dispensed or dispensed >90 days	
	n	%	*n*	%
Year 3	*n* = 33		*n* = 441	
Numeracy	10	31	108	26
Reading	4	13	51	12
Spelling	12	38	161	38
Writing	5	16	121	29
Year 5	*n* = 56		*n* = 1,019	
Numeracy	11	20	233	23
Reading	8	15	207	21
Spelling	21	39	391	40
Writing	16	30	338	35
Year 7	*n* = 52		*n* = 1,076	
Numeracy	15	31	319	31
Reading	10	20	264	26
Spelling	24	48	485	47
Writing	9	18	228	23

Note. Overlapping data on education results and SM dispensed were available for only 2 years. SM = stimulant medication.

Gender differences in reading difficulties have been identified as far back as 1910 (Pickle, 1998), where 85% of children who struggled with reading were boys. This difference has been explained by a number of factors that include neurobiological (Clements et al., 2006), environmental (Olson, 2002), and genetic differences (Willcutt & Pennington, 2000). Functional magnetic resonance imaging studies have suggested that brain activation differs in female participants where the diffuse activation of left and right frontal gyri may assist language tasks with more unilateral activation in males (Clements et al., 2006). It is unclear whether ADHD alters this activation.

Writing problems have been found to be more prevalent among ADHD boys (Yoshimasu et al., 2011). Our study found that boys and girls with ADHD were 3 to 5 times more likely not to reach the State benchmark for writing and spelling compared with their non-ADHD male and female counterparts. Such disadvantage was seen throughout primary school. Children with ADHD may be vulnerable to deficits in written language due to problems with visual integration, motor coordination, working memory, organization, and planning (Kronenberger & Dunn, 2003; Yoshimasu et al., 2011).

Capano, Minden, Chen, Schacher, and Ickowicz (2008) studied 476 children diagnosed with ADHD with a semi structured parent and teacher questionnaire, and identified 18% of children with ADHD having numeracy difficulties irrespective of gender (Capano et al., 2008). Our study found that up to one third of girls and a quarter of boys with ADHD did not reach the minimum standards for numeracy testing, compared with around 11% of non-ADHD females and males. Children with ADHD can have lower intelligent quotient scores, working memory, and processing of information that may affect numeracy scores (Jepsen, Fagerlund, & Mortensen, 2009).

Although boys and girls with ADHD experienced difficulties in all areas of learning, girls with ADHD are more negatively affected in academics (Elkins, Malone, Keyes, Iacono, & McGue, 2011). Our study found that girls with ADHD were more disadvantaged in numeracy and less disadvantaged in writing and spelling compared with ADHD boys that remained throughout their primary schooling years. To the authors' knowledge, this is the first study that reports the disadvantage faced by girls with ADHD in relation to numeracy scores compared with boys with ADHD.

Children who are identified with ADHD should have detailed education assessments to provide targeted interventions, combined with individualized management strategies (Corkum, McKinnon, & Mullane, 2005; Sayal et al., 2010; Wolraich et al., 2011).

The relationship between prematurity and education difficulties has been previously documented. A population study linking the WA Literacy and Numeracy Assessment results with birth details found that females born preterm had significantly lower numeracy scores (Malacova et al., 2008). In addition, studies on moderate preterm and early term births suggest increased special education needs through primary school, and have highlighted the need to follow up this group with appropriate intervention (Chyi et al., 2008). There have been no studies however looking specifically at literacy and numeracy in children with ADHD born moderately preterm or early term. We found an increased risk by degree of prematurity for education failure in children with ADHD. This education failure remained significant for moderate preterm and early term births, irrespective of gender, in the four areas of testing throughout primary school. There may be an increased vulnerability to literacy and numeracy difficulties relating to prematurity and associated with neurodevelopmental disorders. It is important that children born preterm have an early education assessment, and health professionals and parents understand this increased risk of education underachievement in early term births when requesting an induction for no specific obstetric indication, especially if there is a family history of ADHD.

School attendance and absenteeism can reflect a combination of factors, including parental financial resources, employment, educational attainment of parents, and their mental health. The strong hereditary phenotype in parents of children diagnosed with ADHD is recognized, and hence parental inattention may affect the child's educational engagement. Our study identified that children with ADHD were less likely to sit the standardized State exam in both literacy and numeracy, compared with their peers, although the proportions were less than 5%. It has been suggested that schools and parents recognize the difficulties these children encounter and may request that they do not sit the test.

SM may improve early literacy and numeracy scores (Coghill et al., 2014; Scheffler et al., 2009). Our study had overlapping information only for 2 years to look at the percentage of children on SM over the testing period where only 5% to 7% of boys diagnosed with ADHD who were commenced on SM had a prescription dispensed within 90 days of the WALNA testing. We also found a downward trend in failure to reach the benchmark for reading and writing in children who had SM dispensed within 90 days of their testing. However, we do recognize that the small numbers do not allow for robust statistical analysis, and girls were not included due to their small sample size. Further studies need to look at why children with ADHD are not on regular medication and the impact of regular medication on education results in a larger population sample.

Our population study of children diagnosed with ADHD and treated with SM is the largest study of its kind for a distinct population group linked to birth records and standardized academic outcomes through the School Years 3, 5, and 7. The design of this study removes selection, response, and recall bias making it a highly robust study of this population. However, we do acknowledge that our study has some limitations. For this study, children have been defined as having ADHD on the basis of being diagnosed and treated for ADHD using SM. This means that the sample likely represents a more severe group of children with ADHD, particularly for girls, who are less likely to be identified and referred for assessment and treatment than boys with ADHD. We did not have information on ADHD subtypes and comorbidities, where inattentive ADHD is suggested to have a higher association with underachievement (Gau, 2011; Pingault et al., 2011) especially in girls (Massetti et al., 2008). Comorbid externalizing disorders can also affect cognitive performance (Forssman, Eninger, Tillman, Rodriguez, & Bohlin, 2012). We did not adjust for early inflammatory disease, ear disease, or infections, which can increase the risk of ADHD (Silva, Colvin, Hagemann, Stanley, & Bower, 2014) and may also contribute to education failure. Our non-ADHD population, although randomly selected, could include individuals who have ADHD but were not treated with SM, or who were previously diagnosed and treated with ADHD prior to mandatory notification that commenced in August 2003. For this study, we were only able to examine the impact of SM on educational outcomes for 2 years (2004-2005), where we had overlapping information.

Conclusion

The results of this population-based cohort study indicate that children with ADHD are significantly less likely to meet benchmark scores for numeracy, reading, spelling, and writing irrespective of gender over the primary school years. In addition, we found that reducing gestational age independently increased the risk of a child with ADHD having poor reading and numeracy results, even for moderate preterm and early term deliveries. Future population-based prospective studies, which look at comorbid mental health conditions, subtypes of ADHD, intelligent quotients, and early infections or inflammatory conditions, may provide a better understanding of the impact of gestational age and gender differences in relation to ADHD for literacy and numeracy. We must emphasize that all children with ADHD need to have an early detailed psychometric assessment, and evidence-based ongoing support that may include individualized education programs, behavior interventions, and SM (Sayal et al., 2010; Scheffler et al., 2009; Wolraich et al., 2011), to ensure that they leave primary school as educationally prepared as their non-ADHD peers.

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Authors' Note

Ethical approval for this study was obtained from the WA Department of Health Human Research Ethics Committee and the Human Ethics Committee of the University of Western Australia. All authors had full access to all the data in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis. The guarantor affirms that the article is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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