Early Human Development, 2007, 83(2), 115-123.

Prenatal alcohol exposure and attention, learning and intellectual ability at 14 years: A prospective longitudinal study

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ABSTRACT

Background: A range of adverse birth outcomes is associated with heavy prenatal alcohol exposure.
Aim: To examine the effects of moderate levels of alcohol consumption during pregnancy on children's intellectual ability, learning and attention at 14 years of age.
Study design and subjects: The Mater-University of Queensland Study of Pregnancy involves a prospective birth cohort of 7223 singletons whose mothers were enrolled at the first antenatal visit. At 14 years, 5139 mothers and adolescents completed attentional and learning questionnaires, and 3731 adolescents completed psychometric assessments.
Outcome measures: For adolescents, the Wide Range Achievement Test – Revised (WRAT-R) and Raven's Standard Progressive Matrices Test (Raven's) were administered. Mothers completed the Child Behaviour Checklist (CBCL) and adolescents completed the Youth Self Report (YSR). Learning was assessed by a series of questions in the mother and adolescent questionnaires. Maternal measures included the quantity and frequency of alcohol consumption, and the extent of binge drinking.
Results: For consumption of < 1 glass/day in early or late pregnancy, there was no association with any attention, learning or cognitive outcomes. The strongest estimates of effect were found among those consuming ≥ 1 glasses/day. Exposure in late pregnancy was associated with increased prevalence of overall learning difficulty in the unadjusted, although not the adjusted analysis. Binge drinking was associated with a higher prevalence of Raven's score < 85 (1 standard deviation).
Conclusions: Although a number of study limitations need to be considered, the results suggest that consumption at the level of < 1 drink/day does not lead to adverse outcomes in relation to attention, learning and cognitive abilities, as measured in the current research.
Keywords: Prenatal alcohol exposure; Attention; Learning; Intellectual ability; Longitudinal

Consumption of alcohol by mothers during pregnancy poses various risks to the developing child. Even before conception, the toxic effects of alcohol may harm both the egg and sperm. The first weeks after conception are the most critical [1] and [2]. The primary teratogenic effects of alcohol occur during the first 8 weeks, while alcohol exposure later in pregnancy may affect growth and may lead to cognitive impairment, learning difficulty and attention deficit hyperactivity disorder (ADHD) [3], [4], [5], [6] and [7]. Genetic factors linked to alcohol dependence may influence later adolescent psychiatric difficulties [8]. Maternal factors such as smoking, which is often associated with alcohol use, may also increase the teratogenic effects of alcohol [9]. Overall, the effects of alcohol range from fetal alcohol syndrome (FAS) [10], [11], [12] and [13] as a result of heavy, chronic consumption, to a variety of more prevalent and less severe outcomes generally termed fetal alcohol effects (FAE). Although it is clear that chronic, heavy consumption or frequent, heavy, intermittent use leads to full FAS, there has been considerable debate regarding the quantity of alcohol required to produce less severe effects [14].

A number of prospective longitudinal studies have reported no evidence of deficits in cognitive performance [15], [16] and [17] or attention [18], [19] and [20] as a result of maternal alcohol

consumption during pregnancy, while others have concluded that a dose–response relationship is involved [21] and [22]. A recent systematic review of lifestyle factors in pregnancy and subsequent ADHD noted contradictory findings with respect to alcohol exposure and ADHD [23]. The different findings between studies may reflect a number of factors such as the timing of exposure during different stages of pregnancy, the quantity and frequency of consumption, differences in measures of consumption, and the interaction of subtle brain injury with complex psychosocial circumstances that also influence the child's development [5] and [24].

An important limitation of current knowledge is that few non-clinical longitudinal studies have examined the effects of moderate maternal drinking during pregnancy (assessed at the time of pregnancy) on offspring followed from birth through to adolescence. An earlier Australian study reported no significant relationship between low to moderate maternal alcohol use (most were abstainers or consumed < 1 drink/day on average) and newborn clinical and neurological status, however the infants in this research were not followed up over time [25] and [26].

In this study, we examined whether alcohol consumption in early or late pregnancy is associated with education related problems of attention, learning or intellectual ability at 14 years of age.

1. Methods

1.1. Sample

Participants were from the Mater-University of Queensland Study of Pregnancy (MUSP) [27]. Initially, 8556 women attending their first antenatal clinic at the Mater Misericordiae Mothers' Hospital, Brisbane (1981–84), were invited to participate. At the time of hospital discharge, 7629 singleton children remained in the study. Of these, 7223 were enrolled in an ongoing birth cohort study. Mothers were interviewed at the first pregnancy visit (mean = 19.8 ± 6.0 weeks gestation), several days after delivery, at 6 months, and at 5 and 14 years when the child was also assessed. At 14 years, 5139 mothers and adolescents completed attentional and learning questionnaires (the mean age of the adolescents was 13.9 ± 0.34 years, range = 12.5 to 15.5 years), and 3731 adolescents attended the hospital to complete psychometric assessments. Mothers not included in this study were likely to be younger, less educated, financially more disadvantaged and to have consumed more alcohol in early and late pregnancy, and engaged in more binge drinking than included mothers (Table 1).

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Table 1. Social and alcohol intake patterns during pregnancy of those included or not included in study

Characteristic	*N*	Not included, *n* = 2083 (%)	Included, *n* = 5139 (%)	χ^2	*df*	p
Maternal age (years)						
13–19	1181	22.4	13.9			
20–34	5722	73.6	81.5			
≥ 35	319	4.0	4.6	77.6	2	< 0.001
Maternal education						
Incomplete secondary	1305	21.6	16.8			
Complete secondary	4608	63.3	64.7			
Post secondary	1252	15.1	18.5	28.3	2	< 0.001
Family income						
≤ $10,399	2308	44.9	30.1			
> $10,399	4440	55.1	69.9	13.2	1	< 0.001
Alcohol early pregnancy (glasses/day)						
Nil	3609	53.2	49.2			
> 0 to < 1/2	3259	41.5	47.1			
1/2 to < 1	194	3.0	2.6			
≥ 1	107	2.4	1.1	32.8	3	< 0.001
Alcohol late pregnancy (glasses/day)						
Nil	4655	67.8	63.4			
> 0 to < 1/2	2165	26.4	31.6			
1/2 to < 1	248	3.8	3.3			
≥ 1	125	2.0	1.6	19.9	3	< 0.001
Bingeing early pregnancy						
Never	5621	74.9	80.3			
< Half time	1284	20.1	17.2			
≥ Half time	230	5.0	2.5	41.5	2	< 0.001

1.2. Measurement of alcohol consumption

The frequency of alcohol consumption in early pregnancy was measured at the first clinic visit with the following question: "How often do you drink alcohol since becoming pregnant?" Responses consisted of daily, a few times a week, a few times a month, a few times a year, rarely and never. Several days after delivery, mothers were asked: "In the last three months of your pregnancy, how often did you drink alcohol?" Responses consisted of daily, a few times a week, a few times a month, and not at all. Quantity of consumption was measured by asking, "How much alcohol do you usually drink at those times?" Responses consisted of seven or more glasses, five or six glasses, three or four glasses, one or two glasses, less than one glass, and never drink.

Details of the method for calculating the daily average ounces of absolute alcohol (oz/day) are described in an earlier study [28]. The alcohol consumption categories used in further analyses were as follows (oz/day): 0; 0.01–0.249; 0.25–0.499; and 0.5 or more, being equivalent to nil, < 1/2 glass, 1/2 to < 1 glass, and ≥ 1 glass per day. Binge drinking was assessed at the first pregnancy visit by asking, "When you drink alcohol, what part of the time do you have at least 5 glasses?" Responses were coded as nearly half the time or more, less than half the time, and never.

1.3. Child and adolescent outcomes

Attention was measured using the attentional problems subscale of the Child Behaviour Checklist (CBCL) [29]. This subscale has a sensitivity of 75% and a specificity of 99% for the diagnosis of attention deficit hyperactivity disorder (ADHD) [30]. This measure was completed by the mother while the adolescent completed the Youth Self Report [29] and [31]. Scores in the top 10% of each scale were used to define a problem with attention.

Learning was assessed by a series of questions in the mother and adolescent questionnaires. Mothers were asked whether the child had ever repeated a year at school, had ever needed remedial help or had ever attended a special education unit or special school for learning difficulties. A measure of 'previous learning difficulty' was defined as those reporting yes to any of these three questions. Mothers also rated the child's overall current school performance on a five-point scale (1 = below average, 2 = a bit below average, 3 = average, 4 = a bit above average, 5 = above average). Adolescents separately rated their current school performance in English, Mathematics and Science as well as their overall school performance using the same scale. An overall measure of current learning difficulty was derived by summing the ratings of overall school performance by the mother and adolescent. Those scoring ≤ 5 (18.4%) were defined as having 'current learning difficulty'. Adolescents were also administered the reading subscale of the Wide Range Achievement Test – Revised (WRAT-R) [32]. The WRAT-R is an academic achievement test that is significantly correlated with the Wechsler Individual Achievement Test. Cognitive ability was assessed by the Raven's Standard Progressive Matrices Test [33]. This is a widely used test of non-verbal intelligence (mean = 100, S.D. = 15) that was re-standardized for Australian norms in 1986 [34].

Other measures examined included maternal age and education, marital status and total family income at 14 years, prepregnant maternal body mass index (BMI) and level of maternal smoking in early and late pregnancy. Cigarette smoking in pregnancy and possible adverse effects of maternal nutrition were examined because of known associations with study outcomes. Mothers reported the usual number of cigarettes smoked per day (nil, 0–9, 10–19, ≥ 20) at the first clinic visit and within several days after birth for the latter part of pregnancy. BMI was calculated from maternal report at first clinic visit of prepregnant weight and height [35]. Low BMI was defined as < 18.5 (kg/m2). Because outcome is likely to be affected by the number of adverse social risk factors [36] and given

the relatively low number in the high exposure category, a social risk score was constructed. Low maternal education (incomplete high school), maternal age ≤ 19 years at time of pregnancy, single parent status either in pregnancy or at 14 years, and low total family income at either the first pregnancy visit or 14 years follow-up were summed. Because of small numbers of mothers with high risk scores and based on examining the relationship between the risk score and the outcomes, the risk score was reduced to three groups: low (76.1%, 0–1 risk factors), medium (15.4%, 2 risk factors) and higher risk (8.6%, 3–6 risk factors). The risk score was strongly related to outcome measures but weakly associated with exposure.

1.4. Statistical analysis

The relationship between maternal drinking during pregnancy and attention, learning and cognitive outcomes at 14 years of age was examined. Statistical significance was assessed by the Chi-squared test, as well as several one-way between-groups analyses of variance. Analyses were performed using SPSS v.10. Potential confounding factors were examined using multiple linear and logistic regressions. A two-tailed p value of < 0.05 was taken to indicate statistical significance.

2. Results

Drinking during pregnancy was reported by about 50% (early pregnancy) and 36% (late pregnancy) of the women. On average, drinkers consumed 0.146 oz AA/day (between 1/3 and 1/4 glass/day or 2 glasses/week) in early pregnancy and 0.074 oz AA/day (about 1/7 glass/day or 1 glass/week) in late pregnancy. One-fifth of women reported binge drinking on at least one occasion. Gender of the child was unrelated to any of the alcohol exposure variables.

2.1. 14-year outcomes

The relationship between alcohol intake in early and late pregnancy, binge drinking, and adolescent attention, learning and cognitive outcomes is shown in Table 2. Adolescent rating of their performance in English, Maths and Science is not included in the table though was unrelated to reported alcohol intake. Alcohol exposure levels in early pregnancy were unrelated to any of the adolescent outcomes. Alcohol exposure in late pregnancy was statistically associated with ever repeating a grade or requiring remedial help, and with a WRAT-R or Raven's score < 85. The nature of the relationship, however, was not linear, with the unexposed (nil alcohol exposure) and those having ≥ 1 glass/day having the highest prevalence of problems, and those with lower levels of alcohol exposure (< 1 glass/day) having a lower prevalence of difficulties. Binge drinking was statistically associated with a Raven's score < 85, with prevalence of lower Raven's scores increasing with increasing frequency of binge drinking.

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Table 2. Relationship between timing of alcohol in pregnancy and percentage of children with attention and learning difficulties in adolescence

		Alcohol glasses/day												
		Early pregnancy					**Late pregnancy**					**Bingeing**			
		N	**Nil**	**> 0 to < 1/2**	**1/2 to < 1**	**≥ 1**	***N***	**Nil**	**> 0 to < 1/2**	**1/2 to < 1**	**≥ 1**	***N***	**Nil**	**< Half time**	**> Half time**
Attention problems CBCL	No Yes	4656 451	8.6	9.1	6.8	15.5	4670 449	8.9	8.1	9.5	14.3	4640 451	8.8	9.3	9.4
		p =	0.2					0.2					0.9		
YSR	No Yes	4650 457	8.5	9.6	5.3	10.3	4660 459	9.0	8.9	8.3	11.9	4636 455	8.8	10.3	5.5
		p =	0.2					0.8					0.14		
Learning difficulties **Maternal report**															
Overall performance < average	No	4773					4784					4756			
	Yes	318	6.3	6.2	6.1	7.0	318	6.6	5.3	7.1	7.2	319	6.2	6.8	5.5
		p =	1.0					0.3					0.8		
Repeat a grade	No	4441					4449					4426			
	Yes	648	13.3	12.3	9.2	13.8	653	14.3	10.0	9.5	15.5	647	12.4	14.5	13.4
		p =	0.4					< 0.001					0.2		
Remedial help	No	3739					3749					3726			
	Yes	1336	26.6	26.1	23.7	31.0	1339	27.7	23.8	23.5	25.0	1333	26.1	27.2	28.3
		p =	0.7					0.02					0.7		
Special class	No	4724					4736					4709			
	Yes	347	7.3	6.5	3.8	5.2	348	7.4	5.7	6.6	8.3	346	6.8	6.8	8.7
		p =	0.3					0.2					0.2		

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		Alcohol glasses/day												
		Early pregnancy					**Late pregnancy**					**Bingeing**			
		N	**Nil**	**> 0 to < 1/2**	**1/2 to < 1**	**≥ 1**	***N***	**Nil**	**> 0 to < 1/2**	**1/2 to < 1**	**≥ 1**	***N***	**Nil**	**< Half time**	**> Half time**
Adolescent report															
Overall performance < average	No	4959					4970					4944			
	Yes	117	2.4	2.2	1.5	1.8	118	2.6	1.8	1.2	3.6	116	2.2	2.5	2.4
		p =	0.9		0.2		0.9								
WRAT-R reading < 85	No	3200					3211					3187			
	Yes	525	15.6	12.7	11.6	15.9	527	15.3	12.0	10.8	18.3	526	13.9	15.6	14.1
		p =	0.07					0.03					0.5		
Raven's < 85	No	3235					3248					3225			
	Yes	496	14.0	12.8	10.5	11.4	496	14.6	10.9	10.0	11.7	494	12.5	16.2	18.5
		p =	0.6					0.01					0.01		
Composite variables															
Current LD[a]	No	4130					4138					4115			
	Yes	930	18.5	18.3	16.7	21.4	933	19.2	16.6	17.2	26.8	929	18.0	19.9	22.8
		p =	0.9					0.03					0.2		
Previous LD[a]	No	3486					3496					3475			
	Yes	1568	32	30.1	26.9	32.8	1571	33.2	27.3	24.7	29.8	1563	31.0	30.7	33.1
		p =	0.4					< 0.01					0.9		

[a] LD = learning difficulty.

To further examine the relationships in Table 2, an adjusted analysis was performed using a series of logistic models examining CBCL and YSR attention problems, current and previous learning difficulty, and WRAT-R or Raven's scores < 85 as outcomes. These models included the social risk score, maternal BMI < 18.5, smoking in early and late pregnancy, and alcohol intake as a series of indicator variables with no reported alcohol in pregnancy as the reference category (Table 3). Apart from the association between binge drinking and Raven's score < 85, no associations were statistically significant. The strongest association otherwise was between alcohol intake ≥ 1 glass/day and maternal reported attention difficulties in early pregnancy (adj. OR = 1.8, 95% CI = 0.8, 4.0).

Table 3. Strength of relationships expressed as odds ratios (95% confidence interval) between timing of alcohol in pregnancy and attention/selected learning outcomes in adolescence: adjusted analyses[a]

	Attention CBCL	**Attention YSR**	**Current learning difficulty**	**Previous learning difficulty**	**WRAT-R < 85**	**Raven's < 85**
Alcohol early pregnancy (glasses/day)						
Nil	1	1	1	1	1	1
> 0 to < 1/2	1.0 (0.8, 1.3)	1.2 (0.96, 1.5)	1.0 (0.9, 1.2)	1.0 (0.9, 1.1)	0.8 (0.7, 1.01)	0.9 (0.7, 1.1)
1/2 to < 1	0.6 (0.3, 1.4)	0.7 (0.3, 1.4)	0.9 (0.6, 1.5)	0.7 (0.5, 1.1)	0.7 (0.3, 1.4)	0.7 (0.3, 1.5)
≥ 1	1.8 (0.8, 4.0)	1.1 (0.4, 2.8)	0.9 (0.4, 2.0)	0.9 (0.5, 1.7)	1.1 (0.5, 2.6)	0.8 (0.4, 1.5)
n =	4362	4362	4326	4325	3220	3227
Alcohol late pregnancy (glasses/day)						
Nil	1	1	1	1	1	1
> 0 to < 1/2	0.9 (0.7, 1.3)	1.0 (0.8, 1.2)	0.9 (0.7, 1.02)	0.8 (0.7, 0.9)	0.8 (0.7, 1.04)	0.7 (0.6, 0.9)
1/2 to < 1	1.1 (0.7, 1.9)	0.9 (0.5, 1.6)	0.9 (0.6, 1.3)	0.7 (0.5, 1.0)	0.7 (0.4, 1.3)	0.6 (0.3, 1.2)
≥ 1	1.0 (0.5, 2.2)	1.0 (0.5, 2.2)	1.0 (0.5, 1.8)	0.7 (0.4, 1.2)	1.2 (0.6, 2.5)	0.6 (0.2, 1.5)
n =	4361	4361	4325	4324	3218	3225
Binge drinking						
Nil	1	1	1	1	1	1
< Half time	0.8 (0.6, 1.1)	1.0 (0.8, 1.4)	1.0 (0.8, 1.2)	0.9 (0.8, 1.1)	1.1 (0.9, 1.5)	1.4 (1.1, 1.8)
≥ Half time	0.8 (0.4, 1.6)	0.4 (0.2, 1.0)	1.0 (0.6, 1.6)	0.9 (0.6, 1.3)	0.9 (0.4, 1.7)	1.1 (0.6, 2.1)
n =	4354	4354	4318	4317	3213	3220

[a] Variables included in logistic models include level of alcohol intake as indicator variable with nil as reference category, maternal BMI < 18.5, cigarette smoking in early and late pregnancy, and social risk score (low maternal education, maternal age < 19 years, single parent status or low income in pregnancy or at 14 years).

The relationship between the continuous normally distributed outcomes of WRAT-R-reading and Raven's scores and oz/day of alcohol in early and late pregnancy was initially explored using scatterplots. No relationship was apparent. The correlation (Pearson's correlation coefficient) between oz/day of alcohol in early pregnancy and the WRAT-R reading score was − 0.19 and for the Raven's − 0.006, neither being statistically significant. For alcohol in late pregnancy, the correlations were − 0.012 and 0.014, and were not statistically significant. The mean Raven's and WRAT-R scores for different alcohol categories in early and late pregnancy, and for binge drinking, are shown in Table 4, together with differences between these categories when adjusted for social risk, low maternal BMI, and cigarette exposure in early and late pregnancy. For alcohol in early pregnancy, no differences between categories were statistically significant. Reported alcohol intake in early and later pregnancy of < 1 glass/day was associated with Raven's and WRAT-R scores that were slightly higher than the reference category (nil alcohol) though differences were minimal with

few being statistically significant. The category of ≥ 1 glass/day was generally associated with lower scores although these differences were not statistically significant. For binge drinking, the trend for alcohol intake to be associated with lower scores was more prominent, although differences were only statistically significant for the Raven's score.

Table 4. Mean Raven's and WRAT-R reading scores according to level of alcohol intake in early and late pregnancy: unadjusted and adjusted analyses[a]

	Raven's					**WRAT-R (reading)**				
	N	**Mean**	**S.D.**	**Difference**	**Adjusted difference 95% CI)**	***N***	**Mean**	**S.D.**	**Difference**	**Adjusted difference (95% CI)**
Alcohol early pregnancy (glasses per/day)										
Nil	1542	99.9	(15.2)			1536	99.5	(15.1)		
> 0 to < 1/2	1562	100.9	(14.5)	1.0	0.9 (− 0.1, 2.0)	1561	100.7	(14.2)	1.2	1.0 (− 0.05, 2.0)
1/2 to < 1	84	102.1	(12.8)	2.2	2.6 (− 0.6, 5.8)	1561	101.8	(13.7)	2.3	2.2 (− 1.0, 5.4)
≥ 1	39	99.7	(14.3)	− 0.2	0.9 (− 3.7, 5.6)	39	96.4	(14.8)	− 3.1	− 2.5 (− 7.1, 2.2)
F					10.1					7.9
df					7,3219					7,3212
p					< 0.001					< 0.001
Alcohol late pregnancy (glasses/day)										
Nil	2015	99.8	(15.0)			2009	99.6	(14.8)		
> 0 to < 1/2	1052	101.5	(14.6)	1.7	1.6 (0.5, 2.7)	1051	101.0	(14.6)	1.4	1.2 (0.1, 2.3)
1/2 to < 1	106	102.1	(12.2)	2.4	2.3 (− 0.6, 5.1)	106	101.0	(11.9)	1.4	1.2 (− 1.6, 4.1)
≥ 1	52	101.1	(11.8)	1.3	2.1 (− 1.9, 6.1)	52	99.1	(13.8)	− 0.6	− 0.3 (− 4.3, 3.7)
F					10.7					7.8
df					7,3217					7,3210
p					< 0.001					< 0.001
Binge drinking										
Nil	**2575**	**101.0**	**(14.6)**			**2571**	**100.3**	**(14.7)**		
< Half time	**563**	**98.3**	**(15.5)**	**− 2.6**	**− 2.1 (− 3.5, − 0.7)**	**563**	**99.6**	**(14.7)**	**− 0.7**	**− 0.5 (− 1.9, 0.8)**
≥ Half time	**79**	**97.5**	**(13.6)**	**− 3.5**	**− 1.7 (− 5.0, 1.6)**	**79**	**97.3**	**(15.0)**	**− 3.0**	**− 1.7 (− 5.0, 1.6)**
F					**12.6**					**8.5**
df					**6,3213**					**6,3206**
p					**< 0.001**					**< 0.001**

[a] Variables included in linear models include level of alcohol intake as indicator variables with nil as reference category, cigarette smoking in early and late pregnancy, maternal BMI < 18.5, and social risk score (low maternal education, maternal age < 19 years, single parent status or low income in pregnancy or at 14 years).

3. Discussion

In this cohort study, our aim was to examine whether timing or quantity of alcohol consumption in pregnancy was associated with problems of attention, learning or cognition in adolescence. The capacity to do this at higher alcohol exposure levels was limited by a low prevalence of heavy drinkers and a disproportionate loss to follow-up in this group. However, the study is able to address with more certainty the important relationship between low and moderate alcohol ingestion in early and late pregnancy and the study outcomes. For alcohol consumption of < 1 glass/day in early or late pregnancy, no association was evident with any adverse attention, learning or cognitive outcomes. Although the relationships with ≥ 1 glass/day were generally not statistically significant, the strongest estimates of effect were in this group and findings were consistent with the literature on adverse effects of more heavy alcohol intake. Exposure in late pregnancy was associated with increased prevalence of overall learning difficulty in the unadjusted, although not the adjusted analysis. Binge drinking was associated with a higher prevalence of Raven's score < 85 (1 standard

deviation) and lower mean Raven's score. In considering the implications of these findings, a number of study limitations, to be discussed later, need to be considered.

Only one other prospective longitudinal study has reported on comparable outcomes to the current study in a non-clinical sample followed from birth to adolescence, although much larger differences were reported (1/3 S.D.). Streissguth and colleagues [7], [21] and [22], in their Seattle cohort, found a dose–response relationship between maternal alcohol consumption and subtle learning deficits, with early pregnancy drinking (the month or so prior to pregnancy or pregnancy recognition) and binge drinking posing the greatest risk. The typical drinker in this study (based on medians) consumed 1 drink/day on average and 2.5 drinks/occasion. Average scores on word attack and arithmetic measures for adolescents exposed to > 1.5 drinks/occasion in early gestation were one-third of a standard deviation lower than offspring of abstainers [37]. Other findings from this cohort have included subtle yet statistically significant decrements in sustained attention and spatial memory [21]. The adverse outcomes related to higher levels of exposure are consistent with our study, although our findings related to binge drinking and exposure in late pregnancy (the Seattle cohort were not interviewed in late pregnancy).

Several other prospective longitudinal studies have reported deficits related to higher levels of consumption, although offspring were followed from birth to childhood only. Goldschmidt et al. [38] reported that consumption of at least 1 drink/day during the second trimester served as a threshold for spelling and reading deficits among 6-year-old children on the WRAT-R. At 10 years of age, children whose mothers engaged in binge drinking in the second trimester showed deficits in reading recognition and comprehension [39]. Others have also found adverse cognitive outcomes among children, although the samples involved substantially heavier drinkers than those in our cohort [40] and [41].

Several studies have found no relationship between maternal consumption and cognitive outcomes, in samples involving generally low levels of maternal consumption. Fried et al. [18], for example, assessed 272 5- to 6-year-old children of low risk, predominantly middle class mothers, using the McCarthy Scales of Children's Abilities. Given that the average consumption of those in the heavier drinker group was < 1 drink/day and only 5% of the mothers drank more than 1 drink daily, this would appear to be consistent with the current findings regarding low levels of consumption. Greene and colleagues [16] and [19] found no association between maternal consumption and cognitive development or measures of vigilance in a sample of children from socioeconomically disadvantaged backgrounds who were followed up through the first 5 years. Mothers consumed an average of 0.07 oz AA/day (approximately 1/7 glass) according to in-pregnancy reports and approximately 1 glass/day according to retrospective reports.

Finally, in a longitudinal study of obstetric outpatients from a broad range of socioeconomic levels, 313 children were followed up at 6 years of age [17]. Verbal IQ scores and Token Test scores (i.e. receptive language function) were not related to average daily consumption prior to pregnancy recognition. However, they were significantly lower among offspring of mothers with two or more indications of problem drinking (e.g., blackouts, morning drinking). More than 80% of the sample consumed less than 1 drink/day prior to pregnancy recognition.

In interpreting the findings, some limitations of the study should be noted. Due to the low prevalence of heavy drinking among this cohort, together with the high loss to follow-up among heavier drinkers, limited conclusions can be drawn in relation to the effects of heavy drinking on adolescent outcomes. Given study findings in the unadjusted analysis and the limited change in effect measures when controlling for potential confounders it is unlikely that loss to follow-up of those consuming < 1 glass of alcohol/day would alter the reported findings. Although a number of studies have provided evidence of the reliability of self-reported alcohol consumption [42], [43],

[44], [45], [46] and [47], the possibility of under-reporting of consumption during pregnancy must also be acknowledged [19] and [48]. Although calculated average daily intake of alcohol is likely to be imprecise, the implication of under-reporting is that the levels of alcohol reported in our study as not associated with adverse outcomes are likely to represent underestimates of actual alcohol intake. A further limitation concerns the measures of alcohol exposure. Although one of the strengths of the study is that the quantity and frequency of consumption were measured, together with the pattern of consumption as reflected in the measure of binge drinking, the binge drinking measure did not refer to a particular time period in pregnancy and does not provide a precise frequency. Finally, as a measure of nonverbal IQ, the Raven's is limited in its ability to summarize intelligence while the attention scales of the CBCL and YSR are not equivalent to a clinical diagnosis of ADHD. Given our knowledge of exposure in those lost to follow-up and the lack of trends in the data, it is reasonable to conclude that consumption at the level of < 1 drink/day does not lead to adverse outcomes in relation to attention, learning and cognitive abilities, as measured in the current research.

The current findings were based on a large sample of the general population and important variables linked to maternal drinking and child behaviour were taken into account when examining effects. The results support the recommendation of groups such as the Australian National Health and Medical Research Council [49] that averaging < 1 drink/day has no measurable impact on children's mental development. However, identification of alcohol problems among pregnant women and women of childbearing age remains an important public health issue in order to prevent FAS and FAE.

Acknowledgement

The authors thank MUSP participants, the MUSP Research Team, the MUSP data collection teams, the Mater Misericordiae Hospital and the Schools of Social Science, Population Health, and Medicine, at The University of Queensland for their support; and the National Health and Medical Research Council (NHMRC).

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