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Association between Moderate Prenatal Alcohol Exposure and Mathematical Development in Early Childhood

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Master of Public Health

Epidemiology

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Bachelor of Science

Georgia Institute of Technology

2013

Faculty Thesis Advisor: Carolyn Drews-Botsch, PhD

An abstract of

A thesis submitted to the Faculty of the

Rollins School of Public Health of Emory University

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ABSTRACT

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Background: Over half of women of reproductive age report drinking, and 7.6% report drinking during pregnancy. Therefore, it is important to investigate the effects of prenatal alcohol exposure. The aim of this study was to determine the effect of moderate drinking and binge drinking behaviors before and during each trimester of pregnancy on mathematical ability in early childhood.

Methods: Data from this study came from the Fetal Growth and Development Study (FGDS) and the Follow-Up of Development and Growth Experiences Study (FUDGE). FGDS participants were recruited in the neonatal period from infants born between February 1, 1993 and December 31, 1994 at a private and public hospital. The FUDGE was a follow-up of selected infants at around 54 months. The exposures of interest were the average number of drinks per week and binge episodes before pregnancy and in each of the 3 trimesters. Our outcomes of interest were two developmental tests: the Test of Early Mathematical Ability and the Woodcock Johnson Applied Problems subtest. An analysis of variance was run to estimate beta coefficients for each of our main predictors while controlling for confounders.

Results: In the crude analysis, a number of measures of prenatal alcohol exposure were significantly associated with both math ability scores. However, these associations disappeared after controlling for confounders. The single negative association that remained significant was having a binge episode in the second trimester which leads to a 7.4 (95% CI: -14.2, -0.6) point decrease in the Woodcock Johnson score. There were a few positive associations that remained significant which might be due to residual confounding.

Conclusion: The majority of the associations between moderate prenatal alcohol exposure and mathematical development can be explained by confounding.

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BACKGROUND

It has been known for some time that consuming large amounts of alcohol during pregnancy can lead to physical and mental defects, characterized as fetal alcohol syndrome (FAS)[1]. However, there is still debate about the effects of light drinking during pregnancy on cognitive development with some studies finding that drinking leads to a significant negative impact on development while others have not found statistically significant results [2-6].

Alcohol Use during Pregnancy

Consuming alcohol during pregnancy can lead to a number of health problems for the baby including learning disabilities, behavior problems, and physical abnormalities [7]. It has been estimated that the prevalence of Fetal Alcohol Syndrome in the United States is 2 to 7 per 1,000 while prevalence of Fetal Alcohol Spectrum Disorder is estimated to be 2-5% of young school age children [8]. Fetal alcohol syndrome is at the extreme end of the spectrum of fetal alcohol disorders [1].

Both the Surgeon General and Healthy People 2020 have recognized prenatal alcohol exposure as an important issue and have urged pregnant women to abstain from alcohol use [9-11]. According to the 2006 – 2010 Behavioral Risk Factor Surveillance System (BRFSS), 51.5% of non-pregnant women of reproductive age reported drinking alcohol and 15% reported binge drinking in the past 30 days [9]. The prevalence was substantially lower among pregnant women with only 7.6% reporting drinking and 1.4% reporting binging in the past 30 days [9].

According to the 2006 – 2010 BRFSS, women who were 35 – 44 years old, white, college graduates, or employed reported the most alcohol use during pregnancy [9]. In addition, a study of women in Sweden found older age, living in a large city, tobacco use during pregnancy, low social support, strong alcohol habit prior to pregnancy, and social drinking motives were associated with drinking during pregnancy [12]

Mathematical Development

Prenatal exposure to alcohol can lead to a variety of different cognitive defects including verbal, visual, quantitative, attention, and memory abilities [3, 5]. However a number of studies have shown that the greatest deficits are in arithmetic, and that prenatal alcohol exposure has a dose dependent relationship with arithmetic ability [3-5]

There are several different tests to determine math development. The Wechsler Individual Achievement Test (WIAT), Wide Range Achievement Test (WRAT), Stanford-Binet, and Wechsler Intelligence Scale for Children (WISC) have math subtests that have been examined in the literature [3-5, 13].

Biological Reasoning

When a mother consumes alcohol during pregnancy it passes to the fetus through the placenta [14]. There have been studies looking at how this alcohol exposure in utero can affect the brain.

In regard to arithmetic, it has been found that the intraparietal sulcus is activated in all number tasks, while the precentral and inferior prefrontal cortex, left and right middle frontal region, and superior frontal region are activated in mental calculations [15, 16].

In a study done by Meintjes et al, they found that during number tasks controls activated many of the regions of the brain that have already been found to be associated with arithmetic: anterior HIPS, left posterior HIPS, left precentral sulcus, and posterior medial frontal cortex. However, children with FAS or partial FAS didn't have activity in the right and left posterior HIPS and showed activity in the angular gyrus, posterior cingulate, and cerebellar vermis during number tasks [17].

Santhanam et al. conducted an fMRI study looking at brain activation during an arithmetic task. They found that dysmorphic children who were exposed to alcohol prenatally had statistically significantly less activation in the left superior and right inferior parietal region and medial frontal gyrus compared to unexposed children [18]. Nondysmorphic children who were prenatally exposed to alcohol did not differ significantly from unexposed children [18].

Association between Mathematical Development and Prenatal Alcohol Exposure

A recent study, by Jacobson et al., is a longitudinal cohort of 262 African American adolescents [19]. This was a strongly disadvantaged population with only half completing at least 12 years of education and half falling in the level IV or V SES scale. In addition, 82% of mothers reported some drinking during pregnancy. Information about the mothers' alcohol use, while pregnant with the participant, was collected at prenatal clinic visits. This information was used to calculate ounces of absolute alcohol consumed per day. At age 14, the adolescents completed the Wechsler Individual Achievement Test (WIAT) for mathematical reasoning and an adapted number processing test that had been designed by Dehaene [20]**.** The unique part of this study was the fact that they were able to look at distinct aspects of arithmetic: exact and approximate calculation and magnitude comparison. Regression analysis was used to look at the relation between the amount of absolute alcohol intake by mothers and the number processing subtests while controlling for confounders. The study found that prenatal alcohol exposure was associated with the WIAT math subtest scores ($r_s = -0.12$, $P<0.05$). When looking at the subtests of the number processing test, for each additional ounce of absolute alcohol consumed per day during pregnancy there was a 0.17 point decrease on the approximate subtraction subtest, a 0.27 point decrease on the number comparison subtest, and a 0.24 point decrease on the proximity judgment subtest while controlling for confounders ($P < 0.01$, $P < 0.001$, and $P < 0.001$ respectively). These associations were still statistically significant even after controlling for IQ. This study provided insight into what areas of arithmetic might be effected by prenatal exposure in a disadvantaged population. However, the effect of binge behaviors or effect of trimester specific drinking was not evaluated.

The Seattle Longitudinal Study was a population based prospective study designed to look at the effect of drinking alcohol during pregnancy on children's academic and behavioral development [21]. The paper Streissguth, A. P. et al. (1994), discusses the arithmetic subtests used in the Seattle Longitudinal Study [22]. The study consisted of majority white, married, well educated, and middle class mothers [22]. The outcome of interest for this study was the score on the arithmetic subtest of the revised Wechsler Intelligence Scale for Children (WISC-R) at 14 years old (N= 191). The study found that abstaining prior to and during pregnancy, binging before and during pregnancy, the maximum number of drinks on any occasion before and during pregnancy, and the average drinks/occasion before pregnancy were all significantly correlated with arithmetic scores. However, the other alcohol predictors, including a categorized prenatal alcohol exposure variable and average ounces of absolute alcohol per day before and during pregnancy, were not significantly correlated with arithmetic scores. Partial t-tests, adjusting for maternal education, firstborn status, and examiner, were only performed for the "average drinks per occasion prior to pregnancy recognition" predictor. This analysis produced a partial correlation = -0.165, partial t = 2.27, and p = 0.024. While the study did find significant results, a model was only developed for 1 out of the 6 alcohol predictors that were significantly correlated with arithmetic scores. Therefore, we cannot conclude whether the other 5 predictors are still significant after controlling for confounding. In addition, alcohol scores during pregnancy were only for the beginning of pregnancy until the beginning of the 5^{th} month. There was no information of alcohol consumption during the last half of pregnancy.

The purpose of the current study is to look at the effect of light prenatal drinking and binge behavior on development of mathematical ability. Previous studies have consisted of small sample sizes of non-diverse populations. Our study has a slightly larger sample size of a population with diverse races and socioeconomic status. In addition, the current study will look at the effect of trimester specific drinking on math ability.

METHODS

Study Design

This study used data from the Fetal Growth and Development Study (FGDS) and the Follow Up of Development and Growth Experiences Study (FUDGE). The FDGS was a case control study of infants born at either of the two largest delivery hospitals in Atlanta between February 1, 1993 and December 31, 1994 [23-25]. One of the hospitals is a public teaching hospital and the other is a private hospital. Each week, study staff were randomly assigned to identify deliveries at one of the two hospitals thru delivery and labor logs at the public hospital and nursery logs at the private hospital. Only singleton Black and White births with a gestational age between 32 weeks at 42 weeks were included in the study. Participants were selected based on birth weight for gestational age. 100% of infants who were small for gestational age (SGA) and 3% of infants who were appropriate for gestational age (AGA) were selected. Infants were categorized as SGA if their birth weight was less than the 10th percentile for their gestational age, race, and sex.

Data Collection

After infants were selected, informed consent was collected from the infant's mother. Mothers were then interviewed in hospital with 95% of interviews happening within 48 hours of the delivery. The interview consisted of questions about demographics, reproductive history, pregnancy behaviors, and drinking behaviors before and during pregnancy. The response rates differed significantly by hospital: 88% at the public hospital and 68% at the private hospital ($p < .001$). However, the response rates did not differ by SGA status (private hospital: $p = 0.86$, public hospital: $p = 0.62$).

The FUDGE study was a follow-up study of selected infants from the FGDS [24, 25]. All average for gestational age (AGA) infants and all SGA infants whose mothers drank any alcohol in pregnancy were selected as was a random sample of 50% of SGA infants whose mothers did not drink alcohol during pregnancy. 706 infants were selected for the study and 510 of the infants families agreed to participate. The interview was conducted at around 54 (±5) months and included questions about maternal education, maternal employment, childcare, neighborhood characteristics, and child enrichment activities [24]. A psychologist also administered multiple cognitive tests including the Test of Early Math Ability (TEMA) and Woodcock Johnson [24].

Measures

Maternal Drinking During Pregnancy

One of the exposures of interest for this study was maternal drinking behavior during and three months before pregnancy. The questionnaire consisted of questions asking about the average number of days a woman consumed alcohol and on drinking days how many drinks were usually consumed. We used these two variables to estimate the average number of drinks per week for each of 4 time periods: 3 months prior to pregnancy, 1st trimester, 2nd trimesters, and 3rd trimester. We then categorized this continuous variables into four categories: Did not drink, less than 1 drink per week, 1 – 2 drinks per week, and 3 or more drinks per week.

The other exposure we looked at was binging during and prior to pregnancy. Women were asked what the maximum number of drinks they consumed in one day was. Five or more drinks was classified as binging. We categorized the binge variable into 3 categories: Did not drink, drank but did not binge, and binged.

Developmental Tests

There were two outcomes of interest in this study. The first is participant scores on the TEMA. The TEMA measures both informal and formal math concepts and skills in 3 to 8 year olds [26]. There are questions related to relative magnitude, counting and calculation, convention, number facts, and base-ten concepts [26]. For this study we used the TEMA standard score, which has a mean of 100 and standard deviation of 15 [26]. The second developmental test was the applied problems subtest of the Woodcock Johnson. This subtest consisted of math word problems. Both scores were analyzed as continuous outcomes.

Covariates

We looked at several variables found in the literature to confound the relationship between prenatal alcohol exposure and math development. Drug use during pregnancy was categorized as yes or no. Education was categorized as < high school, high school graduate, some college, or college graduate. Family income at delivery was categorized as <$10,000, $10,000 - <$25,000, $25,000 - <$55,000, and >$55,000. Maternal age at delivery was categorized as <20 years old, 20 – 34 years old, and 35+ years old. Race was categorized as White or Black. SGA, single, firstborn, and smoked during pregnancy are all categorized as yes or no.

Statistical Analysis

We selected our variables for inclusion in our model based on the literature. Delivery hospital was highly associated with race, marital status, education, drug use, and income, so we could not include all of these variables in the model at once (Table 1). We chose to just include delivery hospital, because it is strongly associated with social class variables in this population (Table 1). SGA was retained in the model since it was part of the study design. We also chose to include maternal age, smoking during pregnancy, and firstborn status since they were shown in the literature to confound the relationship between prenatal alcohol exposure and math ability. We used analysis of variance (ANOVA) to estimate beta coefficients for our main predictors while controlling for confounders. All analyses were done using SAS statistical software (version 9.4).

RESULTS

Sample Characteristics

Overall, there were 449 participants in our study. Those who did not complete the TEMA and Woodcock Johnson and who had missing data for the alcohol variables were excluded. The total population was evenly distributed by education (24% < high school, 22% high school graduate, 23% some college, and 31% college graduate), race (48% White and 52% Black), marital status (53% not single and 47% single), and first born status (57% not firstborn and 43% firstborn) (Table 2).

Sample characteristics by delivery hospital and size for gestational age are shown in table 2. 147 SGA and 94 AGA births occurred at the private hospital and the 140 SGA and 68 AGA births occurred at the public hospital. The delivery hospital was significantly associated with multiple covariates and predictors among both SGA and AGA infants. Among AGA infants, drug use (1% vs. 12%), education (0% < HS vs. 46% < HS), income (2% < $10,000 vs. 51% <$10,000), maternal age (2% < 20 years vs. 28% < 20 years), race (16% Black vs. 99% Black), marital status (6% single vs. 84% single), and first born status (45% firstborn vs. 24% firstborn), differed by private and public hospital, respectively. Among AGA infants, smoking during pregnancy (11% smoked vs. 16% smoked) did not differ by private and public hospital, respectively.

Table 3 shows the maternal drinking patterns by delivery hospital and size for gestational age. Among SGA infants, delivery hospital differed significantly by all drinking predictors and binging predictors. Mothers at the public hospital had a higher percentage of mothers drinking 3 or more drinks per week compared to the public hospital (1st trimester: 20% vs. 2%, 2nd trimester: 12% vs. 0%, 3rd trimester: 9% vs. 0%, respectively). However, among AGA infants, delivery hospital only differed significantly by drinking during the 3rd trimester and binging during the third trimester. Among AGA infants, 96% of mothers at the public hospital did not drink during the 3rd trimester compared to 74% at the private hospital.

Our outcome of interest include the TEMA Standard and the Woodcock Johnson Applied Problems. The average TEMA score was 90 overall, 97 among SGA and AGA infants at the private hospital, and 81 among SGA infants and 82 among AGA infants at the public hospital (Table 4). The overall average score on the Woodcock Johnson was 96. At the private hospital it was 104 among both AGA and SGA infants and at the public hospital it was 85 among SGA infants and 88 among AGA infants (Table 4).

In a bivariate analysis, the majority of covariates were statistically significantly related to the test scores (Table 5). Marital status, delivery hospital, race, education, income, drug use, maternal age, smoking during pregnancy, and firstborn status were all associated with the TEMA and Woodcock Johnson scores. SGA was the only covariate not associated with the TEMA and Woodcock Johnson ($p = 0.42$ and $p=.13$ respectively).

Association between Prenatal Alcohol Exposure and Mathematical Scores

Table 6 shows the crude and adjusted associations between the alcohol predictors and the math scores. Most of the associations found in the crude analysis disappeared after adjusting for delivery hospital, small for gestational age, maternal age, smoking during pregnancy, and first born status. For drinking before pregnancy, ≥3 drinks per week was significantly associated with an increase on the TEMA (Adj $\beta 1 = 3.6$). For binging before pregnancy, drinking but not binging caused an increase in the TEMA (Adj $\beta 1 = 3.5$). During the 1st trimester, drinking less than 1 drink per week was associated with an increase in TEMA and Woodcock Johnson scores (Adj $\beta 1 = 5.4$ and Adj $\beta 1 = 5.6$ respectively), and drinking 1 – 2 drinks per week led to an increase in the Woodcock Johnson score (Adj $\beta 1 = 5.2$). In addition, drinking but not binging during the first trimester let to a 5.8 point and 5.3 point increase on the Woodcock Johnson and TEMA, respectively. Binging in the 2nd trimester was associated with a decrease in the Woodcock Johnson score (Adj $\beta 1 = -7.4$). Drinking during the 2nd trimester, and drinking and binging patterns in the 3rd trimester were not associated with TEMA or Woodcock Johnson scores.

DISCUSSION

After adjusting for delivery hospital, size for gestational age, maternal age, smoking during pregnancy, and first born status, binging during the 2nd trimester was associated with a ½ standard deviation decrease on the Woodcock Johnson score. There were no other alcohol variables that were associated with a decrease in math ability score. There was a positive relationship between the Woodcock Johnson and having <1 or 1 – 2 drinks per week in the 1st trimester and drinking but not binging in the 1st trimester. There was also a positive relationship between the TEMA and < 1 drink per week in the 1st trimester, drinking but not binging 3 months before pregnancy, and drinking but not binging in the 1st trimester. There were several other positive and negative associations that were significant in the crude analyses but became insignificant once controlling for confounders. There is a possibility that the remaining significant associations could be due to residual confounding. In conclusion, it appears that in our study confounding is what caused the majority of the association between arithmetic and moderate prenatal alcohol exposure.

The results from our study had differences and similarities to the past two main studies that looked at prenatal alcohol exposure and math ability. Jacobson et al. found approximate subtraction, number comparison, and proximity judgment subtests to be statistically significantly related to prenatal alcohol exposure among a disadvantaged population [19]. However, exact calculations were not associated with prenatal alcohol exposure [19]. Because our cognitive tests did not look at subareas of arithmetic, we were not able to determine if a single area, such as proximity judgment, is associated with prenatal alcohol exposure in a diverse population. In terms of the alcohol variables we used, our current study found similar results to the Seattle Longitudinal Study. Streissguth et al. looked at the relationship between several alcohol predictors and math ability [22]. They found that categorized prenatal alcohol exposure was not statistically significantly correlated with arithmetic scores [22]. They did find binging before and during pregnancy to be correlated with arithmetic scores; however, they did not control for any other variables [22]. Our study found statistically significant crude associations between binging and math ability, but they became insignificant after controlling for confounders.

Limitations and Strengths

A major strength of this study is the diverse population. We had an approximately even proportion of White and Black women and a wide range of economic backgrounds. In addition, we also have a large proportion of SGA infants which adds to the diversity of our population as well as increases the population's exposure to alcohol since alcohol is associated with being SGA. However, oversampling woman who were heavy drinkers during pregnancy would have been a better way to increase alcohol exposure.

The specific alcohol questions that were asked during data collection allowed us to look at multiple alcohol predictors. We were able to look at both drinks per week and binge activity. This is important since binge activity has been shown to have a stronger association with math ability [22]. In addition, we were able to look at the effect prior to pregnancy and in specific trimesters, which is a factor other studies have lacked.

Finally, a very unique aspect of our study is our outcome. We were able to look at a test designed solely to look at math ability (TEMA) as opposed to just using a subtest of a bigger study.

The major limitation of this study was the small sample size (N = 449). This could have caused some of the non-significant results. In addition, the very small sample of heavy drinkers limited the way we could categorize the drinking variables.

Finally, residual confounding is a concern in this study. Measures such as parental IQ may contribute to the children's performance on the outcome measure, but we were not able to adjust for this since this information wasn't collected. In addition, there is always the possibility of unknown confounders affecting the association.

Future Directions

Observational studies are what still need to be used in looking at this association of prenatal alcohol exposure and mathematical development. The key piece needed is a large sample size that includes a decent amount of heavy drinkers. Also, there are several different tests used in the literature to describe math development. A consistency in which test is used would be helpful in comparing across studies. Finally, alcohol information collected during pregnancy for each trimester would increase the accuracy of the data and would allow for the researcher to look at trimester specific associations between prenatal alcohol exposure and math ability. To have more confidence in the results, it is important to collect detailed alcohol consumption information multiple times throughout pregnancy.

Public Health Implications

Drinking is very common in women in the United States. Over half of women of reproductive age report drinking [9]. Also, despite recommendations to abstain from alcohol during pregnancy, 7.6% of women report drinking during pregnancy and 1.4% report binging during pregnancy [9]. Therefore, it is important to investigate the effects of prenatal alcohol exposure. However, we did not see an association with regards to moderate prenatal alcohol exposure and arithmetic.

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TABLES

Table 1. Association between Delivery Hospital and Social Class Variables.

	Chi-Square	p-value
Marital Status	291.8	<.0001
Race	304.8	<.0001
Education	243.2	<.0001
Income	282.4	<.0001
Drug Use	66.3	<.0001

Table 2. Characteristics of Mothers and Infants by Delivery Hospital and Size for Gestational Age

			SGA					**AGA**				
	TOTAL		**PRIVATE**		**PUBLIC**			**PRIVATE**		**PUBLIC**		
	N	%	N	%	N	%	P-Value	N	%	N	%	P-Value
Total	449		147		140			94		68		
Drug Use during Pregnancy							<.0001					0.0033
No	395	88%	147	100%	95	68%		93	99%	60	88%	
Yes	54	12%	0	0%	45	32%		1	1%	8	12%	
Maternal Education							<.0001					<.0001
<HS	106	24%	6	4%	69	49%		0	0%	31	46%	
HS grad	100	22%	15	10%	48	34%		13	14%	24	35%	
Some college	103	23%	39	27%	22	16%		31	33%	11	16%	
college grad	140	31%	87	59%	1	1%		50	53%	2	3%	
Maternal Income							<.0001					<.0001
<$10,000	116	26%	4	3%	75	54%		2	2%	35	51%	
$10,000 - <$25,000	69	15%	7	5%	34	24%		7	7%	21	31%	
$25,000 - <$55,000	109	24%	56	38%	14	10%		31	33%	8	12%	
>$55,000	132	29%	78	53%	1	1%		53	56%	0	0%	
Maternal Age							<.0001					<.0001
<20 years old	66	15%	3	2%	42	30%		2	2%	19	28%	
20 -34 years old	335	75%	116	79%	93	66%		79	84%	47	69%	
35+ years old	48	11%	28	19%	5	4%		13	14%	2	3%	
Maternal Race							<.0001					<.0001
White	214	48%	128	87%	6	4%		79	84%	1	1%	

	Black	235	52%	19	13%	134	96%		15	16%	67	99%	
Single/Never Married								<.0001					<.0001
	No	239	53%	130	88%	10	7%		88	94%	11	16%	
	Yes	209	47%	16	11%	130	93%		6	6%	57	84%	
First Born								0.0005					0.0056
	No	254	57%	62	42%	88	63%		52	55%	52	76%	
	Yes	195	43%	85	58%	52	37%		42	45%	16	24%	
Smoked During Pregnancy								<.0001					0.3004
	No	336	75%	116	79%	79	56%		84	89%	57	84%	
	Yes	112	25%	30	20%	61	44%		10	11%	11	16%	

Table 3. Drinking Habits of Mothers by Infants' Delivery Hospital and Infants' Size for Gestational Age

			SGA					AGA				
	TOTAL		**PRIVATE**		**PUBLIC**			**PRIVATE**		**PUBLIC**		
	N	%	N	%	N	%	P-Value	N	%	N	%	P-Value
Total	449		147		140			94		68		
Drinking Before Pregnancy							0.0004					0.0971
Did not drink	147	33%	38	26%	52	37%		26	28%	31	46%	
<1 Drink per week	105	23%	42	29%	19	14%		28	30%	16	24%	
1 - 2 Drinks per week	99	22%	39	27%	24	17%		22	23%	14	21%	
≥3 Drinks per week	98	22%	28	19%	45	32%		18	19%	17	25%	
Drinking During 1st Trimester							<.0001					0.0755
Did not drink	247	55%	76	52%	65	46%		60	64%	46	68%	
<1 Drink per week	117	26%	53	36%	30	21%		24	26%	10	15%	
1 - 2 Drinks per week	49	11%	15	10%	17	12%		6	6%	11	16%	
≥3 Drinks per week	36	8%	3	2%	28	20%		4	4%	1	1%	
Drinking During 2nd Trimester							<.0001					0.6464
Did not drink	357	80%	127	86%	92	66%		80	85%	58	85%	
<1 Drink per week	51	11%	17	12%	15	11%		12	13%	7	10%	
1 - 2 Drinks per week	24	5%	3	2%	16	11%		2	2%	3	4%	
≥3 Drinks per week	17	4%	0	0%	17	12%		0	0%	0	0%	
Drinking During 3rd Trimester							0.0011					0.0008

Did not drink	338	75%	111	76%	92	66%		70	74%	65	96%	
<1 Drink per week	74	16%	29	20%	23	16%		21	22%	1	1%	
1 - 2 Drinks per week	24	5%	7	5%	13	9%		3	3%	1	1%	
≥3 Drinks per week	13	3%	0	0%	12	9%		0	0%	1	1%	
Binging Before Pregnancy							<.0001					0.0615
Did not drink	147	33%	38	26%	52	37%		26	28%	31	46%	
Did not binge	200	45%	79	54%	38	27%		54	57%	29	43%	
Binge	102	23%	30	20%	50	36%		14	15%	8	12%	
Binging During 1st Trimester							0.0194					0.8753
Did not drink	247	55%	76	52%	65	46%		60	64%	46	68%	
Did not binge	157	35%	60	41%	49	35%		29	31%	19	28%	
Binge	45	10%	11	7%	26	19%		5	5%	3	4%	
Binging During 2nd Trimester							<.0001					0.4822
Did not drink	357	80%	127	86%	92	66%		80	85%	58	85%	
Did not binge	70	16%	19	13%	28	20%		14	15%	9	13%	
Binge	22	5%	1	1%	20	14%		0	0%	1	1%	
Binging During 3rd Trimester							0.0001					0.0003
Did not drink	338	75%	111	76%	92	66%		70	74%	65	96%	
Did not binge	94	21%	36	24%	32	23%		24	26%	2	3%	
Binge	17	4%	0	0%	16	11%		0	0%	1	1%	

Table 4. Scores on Mathematical Development Tests by Delivery Hospital and Size for Gestational Age

	TEMA Standard					Woodcock Johnson Applied Problems				
		SGA		AGA			SGA		AGA	
	All	**Private**	**Public**	**Private**	**Public**	**All**	**Private**	**Public**	**Private**	**Public**
n	449	147	140	94	68	449	147	140	94	68
mean	90	97	81	97	82	96	104	85	104	88
s.d.	16	13	15	12	14	17	13	16	14	14
median	90	97	84	95	87	97	103	88	103	90
25th percentile	82	90	64	89	64	87	95	75	95	82
75th percentile	101	106	91	106	91	106	113	97	110	96
minimum	61	61	61	61	61	41	70	41	73	48
maximum	128	128	113	120	108	144	140	124	144	117

Table 5. Associations between Mathematical Development Scores and Covariates

	TEMA Standard			Woodcock Johnson Applied Problems		
	Crude β_1	95% CI	P-Value	Crude β_1	95% CI	P-Value
Delivery Hospital			<.0001			<.0001
Public	-14.9	(-17.5, -12.4)		-18.1	(-20.8, -15.4)	
Private	REF			REF		
Marital Status			<.0001			<.0001
Not Single	15.1	(12.5, 17.7)		17.3	(14.6, 20.0)	
Single	REF			REF		
Race			<.0001			<.0001
Black	-13.2	(-15.9, -10.6)		-17.7	(-20.4, -15.0)	
White	REF			REF		
Education			<.0001			<.0001
< HS	-20.8	(-24.2, -17.4)		-22.8	(-26.5, -19.2)	
HS Grad	-14.1	(-17.6, -10.7)		-15.7	(-19.4, -12.0)	
Some College	-6.5	(-10.0, -3.1)		-6.6	(-10.3, -2.9)	
College Grad	REF			REF		
Income			<.0001			<.0001
<$10,000	-19.3	(-22.7, -15.9)		-22.4	(-25.9, -18.9)	
$10,000 - <$25,000	-11.3	(-15.3, -7.4)		-14.9	(-19.0, -10.7)	
$25,000 - <$55,000	-6.6	(-10.0, -3.1)		-8.3	(-11.9, -4.7)	
>$55,000	REF			REF		
Drug Use during Pregnancy			<.0001			<.0001
No	11.1	(6.8, 15.5)		11.3	(6.5, 16.0)	
Yes	REF			REF		
Maternal Age			<.0001			<.0001
<20 years old	-14.6	(-20.3, -9.0)		-16.7	(-22.8, -10.7)	
20 -34 years old	-5.8	(-10.5, -1.2)		-3.5	(-8.4, 1.4)	
35+ years old	REF			REF		
Smoking during Pregnancy			0.0008			0.0264
No	5.7	(2.4, 9.0)		4.1	(0.5,7.7)	
Yes	REF			REF		
First Born Status			0.0047			0.0079

Yes	4.2	(1.3, 7.1)		4.3	(1.1, 7.4)	
No	REF			REF		
SGA Status			0.4161			0.1338
No	1.3	(-1.8, 4.3)		2.5	(-0.8, 5.8)	
Yes	REF			REF		

Table 6. Estimated Crude and Adjusted Regression Coefficients between Alcohol Usage and Math Development

	Woodcock Johnson Applied Problems			TEMA Standard		
	Crude β_1	Adj β_1[a]	95% CI[b]	Crude β_1	Adj β_1[a]	95% CI[b]
Drinking Before Pregnancy						
Did not drink	REF	REF		REF	REF	
<1 Drink per week	6.1*	1.6	(-2.2, 5.3)	5.2*	2.6	(-1.1, 6.2)
1 - 2 Drinks per week	6.8*	2.9	(-0.9, 6.7)	4.9*	2.6	(-0.9, 6.4)
≥3 Drinks per week	2.3	0.9	(-3.3, 5.0)	2.7	3.6†	(-0.4, 7.6)
Drinking During 1st Trimester						
Did not drink	REF	REF		REF	REF	
<1 Drink per week	7.9*	5.6*	(2.4, 8.8)	6.6*	5.4*	(2.3, 8.5)
1 - 2 Drinks per week	3.7	5.2*	(0.6, 9.7)	1.0	3.3	(-1.1,7.7)
≥3 Drinks per week	-7.3*	-1.2	(-6.8, 4.4)	-5.9*	1.2	(-4.3, 6.6)
Drinking During 2nd Trimester						
Did not drink	REF	REF		REF	REF	
<1 Drink per week	3.6	2.1	(-2.2,6.5)	-0.1	0.1	(-4.2, 4.3)
1 - 2 Drinks per week	-8.6*	-3.5	(-9.8, 2.8)	-7.5*	-1.8	(-8.0, 4.3)
≥3 Drinks per week	-15.2*	-5.8	(-13.3, 1.8)	-13.6*	-4.4	(-11.7, 3.0)
Drinking During 3rd Trimester						
Did not drink	REF	REF		REF	REF	
<1 Drink per week	5.6*	3.3†	(-0.5, 7.1)	3.0	1.7	(-1.9,5.4)
1 - 2 Drinks per week	-0.9	1.3	(-5.0, 7.6)	-0.3	2.8	(-3.3,8.9)
≥3 Drinks per week	-14.8*	-5.1	(-13.5, 3.3)	-13.5*	-4.1	(-12.3,4.0)
Binging Before Pregnancy						
Did not drink	REF	REF		REF	REF	
Did not binge	7.7*	2.9†	(-0.3, 6.1)	6.5*	3.5*	(0.4, 6.6)
Binge	0.0	-1.0	(-5.1, 3.1)	0.0	1.2	(-2.8, 5.1)
Binging During 1st Trimester						
Did not drink	REF	REF		REF	REF	
Did not binge	6.6*	5.8*	(2.8, 8.7)	5.2*	5.3*	(2.4, 8.2)
Binge	-4.2	-0.4	(-5.4, 4.5)	-4.5†	0.2	(-4.6, 5.0)

Binging During 2nd Trimester						
Did not drink	REF	REF		REF	REF	
Did not binge	0.9	1.3	(-2.7, 5.2)	-1.7	-0.2	(-4.0, 3.6)
Binge	-15.8*	-7.4*	(-14.2, -0.6)	-13.5*	-4.8	(-11.4, 1.8)
Binging During 3rd Trimester						
Did not drink	REF	REF		REF	REF	
Did not binge	4.5*	3.0†	(-0.6, 6.5)	2.9	2.3	(-1.2, 5.7)
Binge	-13.4*	-4.0	(-11.5, 3.5)	-14.0*	-4.9	(-12.2,2.4)

†P < 0.10; *P < 0.05

[a]Controlling for hospital, SGA, maternal age, smoking during pregnancy, first born

[b]95% Confidence interval for adjusted β