A Metric of Maternal Prenatal Risk Drinking Predicts Neurobehavioral Outcomes in Preschool Children

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Background: Fetal Alcohol Spectrum Disorders (FASDs), including Fetal Alcohol Syndrome, continue to be high-incidence developmental disorders. Detection of patterns of maternal drinking that place fetuses at risk for these disorders is critical to diagnosis, treatment, and prevention, but is challenging and often insufficient during pregnancy. Various screens and measures have been used to identify maternal risk drinking but their ability to predict child outcome has been inconsistent. This study hypothesized that a metric of fetal "at-risk" alcohol exposure (ARAE) derived from several indicators of maternal self-reported drinking would predict alcohol-related neurobehavioral dysfunctions in children better than individual measures of maternal alcohol consumption alone.

Methods: Self-reported peri-conceptional and repeated maternal drinking during pregnancy were assessed with semi-structured interviews and standard screens, i.e., the CAGE, T-ACE, and MAST, in a prospective sample of 75 African-American mothers. Drinking volumes per beverage type were converted to standard quantity and frequency measures. From these individual measures and screening instruments, a simple dichotomous index of prenatal ARAE was defined and used to predict neurobehavioral outcomes in the 4- to 5-year-old offspring of these women. Study outcomes included IQ, attention, memory, visual-motor integration, fine motor skill, and behavior. Statistical analyses controlled for demographic and other potential confounders.

Results: The current "at-risk" drinking metric identified over 62% of the mothers as drinking at risk levels—23% more than the selection criterion identified—and outperformed all individual quantity and frequency consumption measures, including averages of weekly alcohol use and "binge" alcohol exposures (assessed as intake per drinking occasion), as well as an estimate of the Maternal Substance Abuse Checklist (Coles et al., 2000), in predicting prenatal alcohol-related cognitive and behavioral dysfunction in 4- to 5-year-old children.

Conclusions: A metric reflecting multiple indices of "at-risk" maternal alcohol drinking in pregnancy had greater utility in predicting various prenatal alcohol-related neurobehavioral dysfunction and deficits in children compared to individual measures of maternal self-reported alcohol consumption or a previous maternal substance abuse index. Assessing fetal risk drinking in pregnant women was improved by including multiple indicators of both alcohol consumption and alcohol-related consequences and, if appropriate practical applications are devised, may facilitate intervention by health care workers during pregnancy and potentially reduce the incidence or severity of FASDs.

Key Words: Alcohol Use Screens, Alcohol, Fetal Alcohol Syndrome, Fetal Alcohol Spectrum Disorder, Pregnancy, Risk Drinking.

FETAL ALCOHOL SPECTRUM Disorders (FASDs) are characterized by wide-ranging deficits and anomalies in growth, anatomy, behavior, and cognition (Kodituwakku, 2007; Nash et al., 2006; Sokol et al., 2003; Spadoni et al., 2007). Fetal Alcohol Syndrome (FAS), the most severe expression of the FASDs, is characterized by prenatal and/or postnatal growth retardation, central nervous system dysfunction with or without obvious brain malformation—including various learning disabilities, mental retardation, hyperactivity, and many behavioral problems—and a characteristic pattern of craniofacial malformations (Bertrand et al., 2004; Hoyme et al., 2005; Sokol et al., 2003). The estimated incidence of FAS ranges from 0.3 to 2.0 per 1,000

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live births in the general population (CDC, 2002; May and Gossage, 2001), with a higher incidence within specific groups depending upon socio-demographic, behavioral, clinical, and other risk factors (Abel, 1995; CDC 2002; May et al., 2007, 2008). The combined FASD incidence [e.g., FAS, Alcohol-Related Neurodevelopmental Disorders (ARNDs)] is higher, estimated at about 10 per 1,000 live births (Manning and Hoyme, 2007; O'Leary, 2004; Sampson et al., 1997). However, identification of children and adults with non-FAS FASDs is challenging (Hoyme et al., 2005) in part because of insufficient information on maternal risk drinking during pregnancy (Astley, 2006; Ernhart et al., 1989; Stratton et al., 1996).

Identifying the pattern(s) of maternal alcohol consumption that place a fetus at risk for FASDs remains an important clinical and public health issue as well as a difficult research question (Abel, 2006; Sokol et al., 2003). Many factors associated with alcohol consumption in pregnancy also influence the risk for FASDs (Abel and Hannigan, 1995; Anderson, et al., 2002; Coles et al., 2000; Elliott and Bower, 2004; Magnusson et al., 2007; May et al., 2008). At this time, there is no clearly defined minimum amount of alcohol known to be harmful to embryos or fetuses, nor any accepted "safe" level of drinking during pregnancy (American College of Obstetrics & Gynecology, 2006; Henderson et al., 2007; NIAAA, 2005a,b; Roebuck et al., 1999; Sampson et al., 2000; Sokol et al., 2003). The pattern of alcohol consumption—higher amount, faster rate, and/or greater frequency of drinking—is the most important teratogenic factor (Abel and Hannigan, 1995; Elliott and Bower, 2004; Ernhart et al., 1987; Olney, 2004; West et al., 1994). In one cohort, 0.5 oz of absolute alcohol per day (AAD)—or a weekly average of 1 standard drink per day—and/or 2.5 oz of absolute alcohol per drinking day (AADD) during pregnancy—5 drinks per day—were identified as levels of consumption at which significant neurobehavioral effects occur, although not necessarily FAS (Jacobson and Jacobson, 1994; Jacobson et al., 1993). The implications of these data are not well recognized by clinicians providing care to pregnant women and their children. More than 40% of physicians thought the threshold for FAS was 1 to 3 drinks per day, and 38% thought the "threshold" was 1 or fewer drinks a day (Abel and Kruger, 1998). In a more recent study, 78% believed that avoiding binge drinking might reduce FAS, but less than 44% believed women should abstain from alcohol while pregnant (Elliott et al., 2006). Current recommendations urge women to completely avoid drinking alcohol during pregnancy (Nardini, et al., 2006; NIAAA, 2005a; Surgeon General, 2006), yet the "threshold" for potential problem drinking is considered 4 or more drinks per day for women in NIAAA's (2005b) pocket guide for physicians. In the absence of clear thresholds or dose–response curves, and recognizing the potential for wide-ranging individual differences in susceptibility (e.g., Sokol et al., 1986; Streissguth and Dehaene, 1993), potential maternal under-reporting (Ernhart et al., 1987; Jacobson et al., 2002; Morrow-Tlucak et al., 1989), and various critical periods of exposure for multiple neurodevelopmental outcomes (e.g., Chiodo et al., 2002; Ernhart et al., 1987), abstinence remains the appropriate and prudent public health message.

While thresholds remain problematic, identifying fetal risk drinking is important for prevention of all FASDs. Detecting at-risk drinking in pregnancy is made difficult because of inadequate drinking history during prenatal care, and/or due to maternal under-reporting of pregnancy alcohol consumption. Several quick, economical tools for identifying maternal "fetal-risk" drinking in the antenatal clinic have been developed and applied to pregnant women. These include the CAGE (Ewing, 1984), T-ACE (Sokol et al., 1989), and TWEAK (Chan et al., 1993; Russell et al., 1994). Russell and colleagues (1994) compared these screens and the longer Michigan Alcoholism Screening Test (MAST; Selzer, 1971) and concluded that both the TWEAK and the T-ACE were more sensitive and specific for detecting peri-conceptional "at-risk" drinking than either the CAGE or the MAST. Russell and colleagues (1994) defined risk drinking as an average of ≥1 oz of AAD (or ~14 or more standard drinks/week), after Sokol and colleagues (1985). Each of these screens was developed to overcome intrinsic limitations of maternal self-report of alcohol consumption in pregnancy (Ernhart et al., 1988; Morrow-Tlucak et al., 1989), while maintaining ease of use by healthcare professionals, a critical feature that determines a screen's practical value (cf. American College of Obstetrics & Gynecology, 2006). Yet, the ability of these screens to predict child outcome has been inconsistent. The primary aim of this study was to identify a metric of maternal "at-risk" drinking able to predict child performance on several measures of neurobehavioral function known to be affected by prenatal alcohol exposure. Further, as a single indicator alone may not be sufficient to detect fetal "at-risk" alcohol exposure (ARAE), the utility of a metric may be enhanced by being comprised of several indicators of maternal drinking.

Coles and colleagues (2000) first incorporated multiple measures into a single risk metric: the Maternal Substance Abuse Checklist (MSAC). The MSAC is a cumulative index designed to help identify women at risk for having a child with ARNDs. The MSAC consists of 17 items that capture maternal report of heavy alcohol consumption, maternal age, smoking and other indicators of problem drinking, as well as deleterious medical or social consequences of drinking (Table 1). The MSAC was found to have greater utility than either infant microcephaly or a single measure of maternal "heavy episodic" drinking in identifying infants with prenatal alcohol-related developmental delay assessed by the Bayley Scales of Infant Development (Coles et al., 2000). These results suggest that it may be advantageous to add other indicators, such as the social consequences of problem drinking, to measures of alcohol consumption available from screening tools to improve identification of fetal risk drinking.

This study examined the comparative ability of a metric based upon several indices of maternal self-reported alcohol consumption and effects during pregnancy to examine maternal at-risk drinking and identify prenatal alcohol-related

Table 1. Maternal Substance Abuse Checklist Criteria (Coles et al., 2000)

	Item	Data available in current study	Measure
1	Maternal age ≥24 years	Yes	Maternal report
2	Number of births ≥3	Yes	Maternal report
3	Chronic liver disease present	Yes	Lab assessment
4	Anemia diagnosed	Yes	Lab assessment
5	Began drinking <16 years	No	
6	Drinks 3 or 4 times a week either before or during pregnancy	Yes	Maternal report
7	Drinks ≥2 drinks per occasion either before or during pregnancy	Yes	Maternal report
8	Drinks ≥5 drinks per occasion before pregnancy	Yes	Maternal report
9	Drinks ≥5 drinks per occasion during pregnancy	Yes	Maternal report
10	Drinks throughout pregnancy (does not stop when learns of pregnancy)	Yes	Maternal report
11	Told to drink less before she was pregnant	No	
12	Told to stop drinking before she was pregnant	No	
13	Has tried to quit drinking ever	Yes	CAGE
14	Reports having withdrawal when trying to stop drinking	Yes	MAST
15	Reports ever having had social problems due to drinking	Yes	MAST
16	Has a primary relationship with drinker	Yes	Maternal report
17	Smokes currently	Yes	Maternal report

effects on neurobehavioral performance in children. It was hypothesized that a metric derived from several measures of maternal drinking would better predict neurobehavioral dysfunction in a small sample of prospectively identified 4- to 5-year-old inner-city, African-American children than would any individual measure of maternal alcohol consumption alone. A secondary analysis compared the utility of the MSAC (Coles et al., 2000) to our "at-risk" metric, using only alcohol consumption and alcohol-related consequences variables, to predict neurobehavioral outcome.

METHODS

This study was reviewed and approved by the Wayne State University Institutional Review Board prior to all phases of the study. All adult participants provided informed consent for themselves and their children prior to participation.

Sample

The sample consisted of 77 African-American, inner-city mothers and their children who were participants in a larger ($N = 332$) ongoing study of the long-term effects of prenatal alcohol exposure and nutrition on perinatal development (Beblo et al., 2005; Stark et al., 2005a,b). The mothers were recruited initially at their first antenatal clinic visit to a large, inner-city maternity hospital serving primarily (92%) African-American women. All women reporting peri-conceptional alcohol consumption averaging at least 1.0 oz of AAD—the equivalent of about 2 standard drinks per day—were included. A random sample of approximately 8% of lower level drinkers and abstainers were invited to participate in the comparison group.

The timing of the first prenatal visit varied but all the women in this study initiated care by the 28th week of pregnancy. Maternal exclusion criteria were first antenatal visit later than 28 weeks gestation, metabolic disorders, and being HIV-positive. From the 332 mother–infant dyads completing the original study, 200 were selected as a pool for recruiting participants into this study: 100 children were chosen as potential participants because their mothers reported drinking the higher levels of peri-conceptional alcohol use (AAD0) among the cohort; another 100 age- and sex-matched children born to the abstaining and light drinking women were selected based on sex and date of birth as potential matching controls in the comparison group. Of the 200 potential participants, 141 (70.5%) were contacted successfully. Of the 141, 128 (90.8%) initially agreed to participate, 8 (5.7%) refused, 4 (2.8%) moved out of state, and 1 child was deceased. Of the 128, 77 (60.2%) participated in testing, while 51 families (39.8%) were "passive refusers." Preliminary analyses comparing those who had agreed to participate but did not show ($n = 51$) with those who did participate ($N = 77$) found no differences between the 2 groups on child sex, maternal age at the time of conception, or peri-conceptional maternal alcohol consumption. Although 77 children were tested, complete data were available for only 75. One child in the alcohol-risk group (defined below) had partial data because of significant behavior problems and refused to cooperate in most of the procedures and another child in the non-alcohol-exposed group, who was later diagnosed with autism, was unable to complete any tasks.

Assessment of Maternal Alcohol Use

Antenatal interviews at each prenatal clinic visit examined each mother's alcohol consumption and drug use during the previous 2 weeks. The mother was questioned about her drinking on a day-by-day basis and asked to describe her alcohol consumption, both at the time of the first visit, which on average occurred at the 16th week of gestation (range: 5 to 28 weeks) and retrospectively about drinking around the time of conception, using a semi-structured interview (Sokol et al., 1985). Drinking volume was noted for each day, converted to ounces of AAD based on beverage type, and then averaged across visits to create consumption variables for the various periods, including around the time of conception (AAD0), the 2-week period immediately before the first antenatal visit (AAD1), and an average across the pregnancy from reports at all visits (AADXP). As noted above, some women were not interviewed until after the completion of their first trimester. As a proxy for early drinking, alcohol consumption around the time of conception (AAD0) was included in the within-pregnancy average measure (AADXP) for all women (cf. Burden et al., 2005; Jacobson et al., 1993, 1994; Nordstrom-Bailey et al., 2004). Based on these 2-week histories, average amount (ounces) of absolute alcohol drunk per drinking day for the peri-conceptional (AADD0), first antenatal visit (AADD1), and across-pregnancy assessments (AADDXP) were also calculated. These weekly average and daily use measures have been used effectively for years to examine prenatal alcohol-related outcomes (e.g., Beblo et al., 2005; Burden et al., 2005; Jacobson et al., 1994, 1998, 2002; Nordstrom-Bailey et al., 2004).

Table 2. Selected MAST Items Used to Assess Social Problems Due to Drinking (Selzer, 1971)

Item no.	Item
7	Have you ever gotten into physical fights when drinking?
8	Has drinking ever created problems between you and a near relative or close friend?
10	Have you ever lost friends because of your drinking?
11	Have you ever gotten into trouble at work because of drinking?
12	Have you ever lost a job because of drinking?
13	Have you ever neglected your obligations, your family, or your work for 2 or more days in a row because you were drinking?
21	Have you been arrested more than once for driving under the influence of alcohol?
22	Have you ever been arrested, even for a few hours because of other behavior while drinking?

Table 3. Alcohol Consumption Measures and Problem Drinking Screens

	Cut-point for "ARAE" metric	Percent "at-risk"
ARAE components		
AA/day at conception (AAD0)	≥1.0 oz	50.6
AA/day at first prenatal visit (AAD1)	≥0.5 oz	1.3
AA/day across pregnancy (AADXP)	≥0.5 oz	24.7
AA/drinking day at conception (AADD0)	≥2.5 oz	45.5
AA/drinking day at first prenatal visit (AADD1)	≥2.5 oz	3.9
AA/drinking day across pregnancy (AADDXP)	≥2.5 oz	42.9
CAGE	≥2	28.8
T-ACE	≥3	36.1
MAST	≥5	27.4
At-risk metrics		
MSAC (Coles et al., 2000)		51.9
ARAE (the current index)		62.3

The ARAE metric was considered positive for "at-risk" drinking if the cut-point criterion was met for any one of these 9 measures. AA = ounces of absolute alcohol.

In addition to these consumption measures, the MAST and the T-ACE and CAGE questionnaires for alcohol abuse were also administered at the first prenatal visit. The 25-item MAST, designed to identify psychosocial problems related to alcohol abuse and dependence (Selzer, 1971), asks questions such as "Have you ever awakened in the morning after some drinking the night before and found that you could not remember a part of the evening before?" (see Table 2 for other examples). Items receive weighted scores of 1, 2, or 5 for a possible maximum score of 53. A score of 5 or more on the MAST indicates that the respondent is at high risk for alcohol abuse or dependence.

The T-ACE screen consists of 4 items: (1) How many drinks does it take to make you feel high? (**T**olerance); (2) Have people **A**nnoyed you by criticizing your drinking? (3) Have you every felt you should **C**ut down on your drinking? and (4) Have you ever had a drink first thing in the morning to steady your nerves or get rid of a hangover (i.e., an "**E**ye-opener")? A positive response of more than 2 drinks on the tolerance question scores 2 points and 1 point is scored for positive answers on the other questions. A total score of 2 or more on the T-ACE is used typically as a criterion for clinical significance (American College of Obstetrics & Gynecology, 2006; Sokol et al., 1989). For the current analyses, we used a T-ACE cut-off of 3 or more, consistent with Russell and colleagues (1994; see also Bradley et al., 1998; Chan et al., 1993; and below). The CAGE consists of 3 T-ACE items, retaining the questions on cutting down, being annoyed, and having an "eye-opener," and substituting for the tolerance question another addressing guilt: "Have you ever felt bad or **G**uilty about your drinking?" One point is scored for each positive answer and a score of 2 or more on the CAGE is considered clinically significant (Ewing, 1984; Mayfield et al., 1974).

From these individual alcohol assessment measures and instruments, a simple dichotomous metric of prenatal ARAE was defined and used to distinguish children "at risk" from those who were not. As our objective was to identify every child who had been exposed to maternal drinking at fetal risk levels, every woman positive on any one of the drinking measures was classified as drinking "at risk" and women negative on all measures were not. The "yes/no" ARAE metric was deemed to be positive if any one of the following 2-week average criteria was met: average ounces of AAD around the time of conception (AAD0) ≥1.0; or ounces of absolute alcohol per drinking day at conception (AADD0) ≥2.5; or average AAD at the first prenatal visit or across pregnancy (AAD1 & AADXP) ≥0.5; or absolute alcohol per drinking day at the first prenatal visit or across pregnancy (AADD1 & AADDXP) ≥2.5 ounces; or a MAST ≥5; or the CAGE ≥2; or the T-ACE ≥3. With the exception of the T-ACE, all criteria (see Table 3) are current standard definitions of "at-risk drinking" (cf. American College of Obstetrics & Gynecology, 2006; Jacobson and Jacobson, 1994; Russell et al., 1994). The American College of Obstetrics & Gynecology (2006) currently recommends using a cut-point of 2 for the T-ACE (Sokol et al., 2003) to maximize sensitivity in identifying women drinking at any level that may put the fetus at risk. As the aim of this research was to identify young children who were exposed at levels producing prenatal alcohol-related neurobehavioral dysfunction and deficits, we used a more conservative T-ACE criterion of 3 or more, consistent with other researchers (e.g., Bradley et al., 1998; Russell et al., 1994).

Approximation of the Maternal Substance Abuse Checklist. To examine the relation between a previously defined global metric of maternal alcohol risk and child neurobehavioral outcomes, we computed an approximation of the MSAC as developed by Coles and colleagues (2000). The MSAC consists of 17 maternal behaviors and other characteristics variously related to "at-risk" drinking (see Table 1). Coles and colleagues (2000) found that a score of 7 of 17 on the MSAC predicted significant infant developmental delay on the Bayley and "compromised attentional regulation skills" as indicated by higher baseline levels of behavioral arousal and less efficiency in neurophysiological encoding of auditory or visual stimuli (Kable and Coles, 2004). As information similar to the MSAC was available for 14 of the 17 items in the current cohort, a prorated score of 6 was used to define "at risk" with our approximation of the MSAC. Most of the 14 available items were based on maternal report. Evidence that a women tried to "quit drinking" (MSAC item no. 13) was obtained from the "cut-down" item of the T-ACE and CAGE screens. Withdrawal symptoms and deleterious social consequences related to alcohol use/abuse were obtained from the MAST. Answering "Yes" to any of 8 MAST items (Table 2) assessing social problems due to drinking was considered positive for the MSAC social problems item (no. 15). The MSAC item for diagnosis of anemia was estimated from the 24-week gestation blood laboratory data. Women were considered positive for anemia if hemoglobin levels were below 10.2 or hematocrit was below 34%, using criteria for third-trimester pregnant women (CDC, 1998).

Neurobehavioral Assessments

At 4 years of age, children were assessed in the laboratory and administered a selected battery of measures assessing IQ, attention, memory, visual-motor integration, fine motor ability, and behavior. These measures were chosen because they previously had

been identified as sensitive to alcohol's teratogenic actions (e.g., Brown et al., 1991; Burden et al., 2005; Jacobson, 1998; Kodituwakku, 2007; Nordstrom-Bailey et al., 2004; Riley et al., 2003; Streissguth et al., 1998).

IQ. The Wechsler Preschool and Primary Scale of Intelligence–Revised (WPPSI-R; Wechsler, 1989) is a general measure of intelligence appropriate for children as young as 4 years of age yielding scores for total IQ, verbal and performance IQ scales, and 12 individual subtests. The WPPSI-R has been used widely and is regarded as the "gold standard" for evaluating general cognitive function in preschool children.

Neurobehavioral Test Battery (NTB). The NTB assessing age-appropriate aspects of executive function and fine motor skills is a composite of 4 computerized tests from the Behavioral Assessment and Research System (Anger et al., 1996) plus 4 noncomputerized tests (Rohlman et al., 2001, 2003). The noncomputerized tests include 2 from the Pediatric Environmental Neurobehavioral Test Battery (Amler and Gibertini, 1996): the Purdue Pegboard Test (Gardner and Broman, 1979; Tiffin and Asher, 1948), and the Object Memory Test (Mahurin et al., 1992). See Table 4 and below for further description of the complete test battery. The NTB was individually administered with instructions relying on demonstration and practice trials. Many of the subtests in the NTB have been used widely and validated in other forms (Rohlman et al., 2001). The NTB in its present form was validated in a sample that included both English- and Spanish-speaking 4- to 6-year-old children (Rohlman et al., 2001, 2003). Data from one of the NTB tests, Match-to-Sample, was not included in the final analyses because none of the children, regardless of prenatal alcohol exposure, could complete this task even after its administration was simplified in several ways (e.g., increasing total presentation time and reducing sample complexity).

Personal Behavior Checklist (PBCL-36). The PBCL-36 has been validated as a sensitive measure of behavioral problems arising specifically from prenatal exposure to alcohol and has been found to be independent of age, sex, or IQ (Streissguth et al., 1998). The 36-item PBCL assesses 7 behavioral domains including Communication and Speech, Personal Manners, Emotion, Motor Skills and Activities, Academic/Work Performance, Social Skills and Interactions, and Body and Physiologic Functions.

Flexible Item Selection Task (FIST). The FIST measures abstraction and cognitive flexibility aspects of executive function (Jacques and Zelazo, 2001). The FIST is a simpler, age-adjusted version of the Wisconsin Card Sorting Test (WCST) and makes fewer instructional demands than the WCST. Although administered to the study participants, this task was not included in any analyses because children in this sample could perform this task.

Table 4. Neurobehavioral Test Battery

Instrument	Task	Domain
BARS	Digit Span	Memory and Attention
BARS	Symbol Digit	Information Processing Speed
BARS	Finger Tapping	Response Speed; Fine Motor Coordination and Attention
BARS	Match to Sample	Visual Memory
BARS	CPT	Sustained Attention
	Object Memory	Recall, Delayed, and Recognition Memory
	Purdue Pegboard	Fine Motor Dexterity
PENTB	Divided Attention	Working Memory and Attention
PENTB	Visual Motor Integration	Visual Motor Integration

The battery included items from the "BARS" (Behavioral Assessment and Research System, Anger et al., 1996), the "PENTB" (Pediatric Environmental Neurobehavioral Test Battery, Amler and Gibertini, 1996), the Purdue Pegboard Test (Gardner and Broman, 1979; Tiffin and Asher, 1948), and the Object Memory Test (Mahurin et al., 1992).

Caregiver Measures. The primary caregiver, usually the biological mother (96%), was interviewed at the same time as the child's testing. Home environment and parenting quality were assessed using a semi-structured interview based on a modified Home Observation for Measurement of the Environment (HOME; Caldwell and Bradley, 1984), similar to Frankenburg's Home Screening Questionnaire (Frankenburg and Coons, 1986), and incorporating the interview portion of the HOME plus laboratory observations of parent–child behavior. Socio-economic status (SES) was estimated with the widely used Hollingshead's 4-factor index (Hollingshead, 1975). To control for a possible confounding influence of caregiver intellectual ability, caregivers were given the Performance IQ scale from the Wechsler Adult Intelligence Scale–Revised (WAIS-R; Wechsler, 1981). Although only the performance subscale of the WAIS-R was given because of time restrictions, this subscale has excellent reliability (split-half reliability coefficient = 0.93; test–retest = 0.89) and is highly correlated with full-scale IQ (Wechsler, 1981; $r = 0.91$ across all age groups).

Procedure

Pregnancy and neonatal data were available from the database generated with the original cohort (cf. Beblo et al., 2005; Stark et al., 2005a,b), and from chart review. At age 4 to 5 years, the child and primary caregiver (usually the birth mother) were tested in our research facility. Female research assistants were trained in all measures and approved for testing by the first author (LMC) and an additional clinical psychologist certified in WPPSI administration. Research assistants were blind to the child's exposure status interviewed each child and mother independently.

Data Analyses

Prior to analyses, checks were performed for missing and out-of-range data and for deviations from normality. Because a control variable cannot be a confounder unless it is related to both exposure and outcome, association with either exposure or outcome can be used as a criterion for statistical adjustment (Schlesselman, 1982). In this study, control variables were selected for inclusion in the regression analyses based on their relations to outcome measures (Kleinbaum et al., 1988). All control variables that were even modestly related to each outcome ($p < 0.10$) were adjusted statistically by regressing the outcome on prenatal alcohol exposure level and the control variables related to that outcome. Pearson's "r" correlations were used to examine the relations of each control variable to each outcome. The covariates used included child's age and sex, caregiver education and marital status, SES, the HOME total score, mother's age at initial prenatal screen, caregiver performance IQ, maternal custody, and maternal prenatal smoking (cigarettes/day). After controlling for confounders, the associations of the specific neurobehavioral outcomes with prenatal alcohol exposure measures and the "at-risk" alcohol metric were evaluated with one-tailed tests with a significant alpha set at $p < 0.05$. The one-tailed test and this level of significance were used because we had specific a priori, directional hypotheses that "at-risk" alcohol consumption would produce dysfunctions or deficits in each neurobehavioral outcome, reflecting the clinical expectations and the practical value of all alcohol consumption measures or metrics. A stepwise regression analysis was utilized entering all covariates in the first step ($p < 0.05$ to enter, $p < 0.10$ to remove) with prenatal exposure variable in the second and final step. In the results of the regression analyses (Table 6), bivariate correlations of prenatal alcohol exposure with endpoints are shown as Pearson's "r"

Table 5. Sample Characteristics ($N = 75$)

	Mean or %	SD	Minimum	Maximum
Maternal				
Age at delivery (years)	25.30	5.60	15	38
Average AA per day				
At conception	1.21	1.60	0.00	10.00
At first prenatal visit	0.04	0.12	0.00	0.76
Across pregnancy	0.32	0.50	0.00	3.33
AA per drinking day				
At conception	2.55	2.56	0.00	10.00
At first prenatal visit	0.36	0.96	0.00	4.80
Across pregnancy	2.36	2.43	0.00	10.00
CAGE total score	0.88	1.15	0	4
T-ACE total score	1.72	1.66	0	5
MAST total score	4.93	8.26	0	38
MSAC total score	5.90	2.85	0	13
Primary caregiver				
Biological mother (%)	96.05	–	–	–
Education (years)	12.01	1.38	8	16
Marital status (% married)	6.60	–	–	–
SES: Hollingshead 4-Factor Index	25.74	9.36	11	48
Child				
Age at assessment (years)	4.42	0.38	3.93	5.63
Sex (% male)	53.20	–	–	–
WPPSI-R				
Full Scale IQ	82.03	11.77	50	107
Verbal IQ	81.63	11.80	55	113
Performance IQ	86.72	13.22	51	115

AA = absolute ounces of alcohol.

and relations to endpoints after adjustment for confounders are shown as "β," the standardized regression coefficient. Determination of significant effects was based upon the β values.

RESULTS

Sample Characteristics

Mean gestational age at the mothers' initial antenatal clinic visit was 16.0 weeks (SD = 5.6); only 35% of the mothers obtained prenatal care during their first trimester. The mothers were poorly educated (see Table 5): >35% had not graduated from high school, <20% attended some college, and <1% had a college degree. They were predominantly lower SES; 75% had an average total household annual income <$20,000. Only 6.6% were married, and the average maternal age at the first prenatal visit was 25.7 years old; 4% were <18 years of age at the time of delivery. Women below the legal age of drinking reported similar levels of alcohol consumption as women at or above the legal age of 21. In addition, there were no differences in the number of reported negative consequences of alcohol use (e.g., via the MAST; all p-values >0.10) between these 2 age groups. However, women ≥30 years of age reported more average alcohol consumption at conception (AAD0; $t = -5.1$, $p < 0.001$) and across pregnancy (AADXP; $t = -2.0$, $p = 0.05$), as well as more alcohol-related negative consequences (MAST; $t = -3.7$, $p < 0.001$), than younger women.

The mean child age at testing was 4.4 years (SD = 0.4); 53.2% were male. At testing, only 3 children were not in the custody of their biological mother; one mother was deceased (Table 5). Although the children in this study performed more than 1 SD lower than national norms on the IQ assessment, this is consistent with results from other research groups evaluating urban African-American children (Jacobson et al., 2004; Nordstrom-Bailey et al., 2004). Children in this sample scored significantly worse on the Verbal IQ index than on the Performance IQ index ($t = 4.04$, $p < 0.001$; Table 5).

Prenatal Alcohol Exposure and the At-Risk Alcohol Exposure Metric

Table 5 and Fig. 1 provide information on maternal report of alcohol consumption both prior to and throughout pregnancy. Average ounces of AAD and average ounces of AADD are shown in Table 5. Women reported less alcohol consumption at the first prenatal visit than before they knew they were pregnant, that is, in the peri-conceptional period. Reflecting the recruitment criteria used to obtain a balanced sample of high- and low-risk children, 50.6% of the mothers reported drinking at risk levels during the peri-conceptional period (AAD0). However, only 24.7% reported drinking at risk levels during pregnancy based upon the drinking measures alone (AADXP). In contrast, the ARAE metric defined 62.3% of the children as exposed to at risk levels of alcohol whereas the MSAC measure defined just over half (52%) as at risk (Table 3). Two of the standard alcohol risk drinking instruments, the CAGE and the MAST, defined similar percentages of "at-risk" children as AADXP, approximately 28% (Table 3). The T-ACE, using the same cut-point of 3 (cf. Bradley et al., 1998; Russell et al., 1994) chosen for the ARAE metric, defined 36% of children as being at risk.

Prenatal Alcohol Exposure and Neurobehavioral Endpoints

Regression analyses were used to examine relations between several indicators of prenatal alcohol exposure and the 36 separate neurodevelopmental outcomes across 10 tests. All significant effects for all alcohol measures and metrics on all outcomes were in the predicted direction, showing poorer performance, dysfunction and/or deficits. Overall examination of these relationships, summarized in Table 6, shows the greater number of significant relations of these outcomes with the ARAE metric than with the individual alcohol consumption measures.

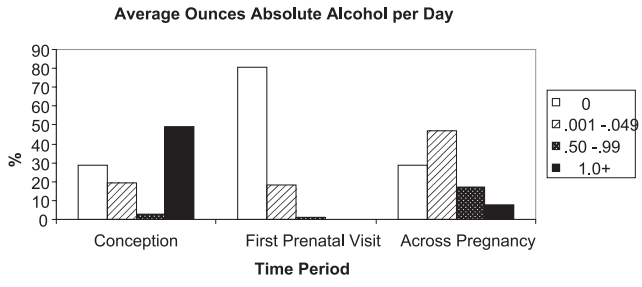

Fig. 1. Maternal self-reported alcohol consumption.

Table 6. Relations Between Prenatal Alcohol Exposure Measures and Neurobehavioral Outcomes

	Current "at-risk alcohol exposure" metric (ARAE)		AA/day across pregnancy (AADXP)		AA/day at conception (AAD0)		AA/drinking day across pregnancy (AADDXP)		AA/drinking day at conception (AADD0)		MSAC[a] metric	
	r	*β*	*r*	*β*	*r*	*β*	*r*	*β*	*r*	*β*	*r*	*β*
WPPSI												
Animal pegs	0.02	−0.04	0.07	0.02	0.02	−0.04	−0.06	−0.07	0.04	0.00	−0.06	−0.03
Arithmetic	−0.36***	**−0.33*** **	−0.08	−0.03	−0.22**	−0.16	−0.13	−0.10	−0.14	−0.09	−0.17*	−0.14
Block design	−0.09	−0.04	−0.02	0.06	−0.09	0.00	−0.05	−0.01	−0.07	0.00	−0.10	−0.07
Comprehension	0.01	0.01	0.12	0.16	0.06	0.11	0.01	0.05	0.05	0.07	0.07	0.06
Geometric design	−0.20**	−0.17	−0.08	0.00	−0.15	−0.08	−0.18*	−0.16	−0.12	0.10	−0.07	−0.01
Information	−0.34***	**−0.27****	0.02	0.15	−0.11	0.00	−0.15	−0.10	−0.16*	−0.11	−0.10	0.04
Mazes	−0.23**	**−0.19***	−0.15	−0.08	−0.26**	**−0.20****	−0.20**	**−0.19***	−0.21**	**−0.19***	−0.23**	−0.15
Object assembly	−0.17*	−0.10	−0.05	0.10	−0.12	0.03	−0.11	−0.05	−0.11	−0.03	−0.12	−0.04
Picture completion	−0.32***	**−0.28*****	−0.08	−0.12	−0.09	−0.03	−0.12	−0.09	−0.13	−0.08	0.04	0.07
Similarities	−0.20**	**−0.21***	0.09	0.08	−0.04	−0.06	−0.10	−0.11	−0.08	−0.09	−0.06	−0.11
Sentences	−0.17*	−0.16	−0.13	−0.04	−0.27**	−0.15	−0.17*	−0.09	−0.17*	−0.09	−0.14	−0.18
Vocabulary	−0.09	−0.06	0.09	0.16	0.01	0.08	0.03	0.04	0.03	0.04	0.02	0.08
Verbal IQ	−0.20**	−0.13	0.02	0.15	−0.13	−0.03	−0.16*	−0.12	−0.16*	−0.10	−0.13	−0.05
Performance IQ	−0.30***	**−0.22****	−0.12	0.02	−0.20**	−0.07	−0.19*	−0.14	−0.20**	−0.13	−0.14	−0.03
Full IQ	−0.31***	**−0.24****	−0.03	0.10	−0.16*	−0.03	−0.17*	−0.12	−0.17*	−0.10	−0.12	−0.02
Symbol digit Number correct	−0.36***	**−0.26****	−0.25**	−0.13	−0.30***	**−0.19***	−0.28***	**−0.19***	−0.29***	**−0.21****	−0.30***	−0.14
Digit Span–Forward	−0.27***	**−0.23****	−0.20**	−0.14	−0.30***	**−0.26****	−0.30***	**−0.29*****	−0.33***	**−0.31*****	−0.29***	**−0.28****
VMI motor t-score	−0.25**	**−0.21***	−0.19*	−0.12	−0.22**	−0.14	−0.16*	−0.14	−0.16*	−0.13	−0.10	−0.01
Pegboard												
Total pegs	−0.23**	**−0.23****	−0.16**	−0.09	−0.23**	**−0.18***	−0.20**	−0.14	−0.19**	−0.14	−0.22**	**−0.19***
Total pegs-both hands	−0.25**	**−0.25****	−0.17*	−0.14	−0.28***	**−0.27****	−0.26***	**−0.23****	−0.25**	**−0.22****	−0.27***	**−0.24****
Total pegs-left hand	−0.24**	**−0.24****	−0.11	−0.04	−0.17*	−0.11	−0.15*	−0.09	−0.15*	−0.10	−0.18*	−0.16
Total pegs-nondominant hand	−0.25**	**−0.24****	−0.15	−0.07	−0.21**	−0.14	−0.19*	−0.11	−0.18*	−0.12	−0.18*	−0.12
CPT number of hits	−0.14	−0.14	−0.14	−0.14	−0.18*	−0.18	−0.26**	**−0.26****	−0.22**	**−0.22****	−0.22**	**−0.22***
Object memory	0.06	0.09	0.12	0.19	0.17*	**0.23****	0.24**	**0.26****	0.25**	**0.26****	0.07	0.13
Finger tapper												
No. taps, long condition	−0.22**	**−0.20***	0.00	−0.04	−0.07	−0.12	−0.15*	**−0.19***	−0.33***	**−0.34*****	−0.19**	−0.17
Total no. taps without singing	−0.21**	**−0.19***	0.00	−0.05	−0.07	−0.12	−0.18*	**−0.21***	−0.16*	−0.18	−0.20**	−0.18
Divided attention[b]												
Left hand tap with words	−0.20**	**−0.26****	0.01	−0.05	−0.05	−0.11	0.03	0.01	0.04	0.02	−0.05	−0.11
Right hand tap with words	−0.18*	**−0.25****	0.14	0.07	0.05	−0.02	0.06	0.04	0.07	0.05	0.00	−0.07
Total no. taps with singing	−0.24**	**−0.22****	−0.02	−0.06	−0.10	−0.15	−0.15*	**−0.19***	−0.17*	**−0.19***	−0.10	−0.10
PBCL												
Academic and work performance	0.18*	**−0.23****	−0.04	−0.10	−0.05	−0.10	−0.02	−0.04	−0.01	−0.03	0.08	0.03
Communication and speech	−0.21**	**−0.21***	−0.08	0.04	−0.10	−0.10	−0.10	−0.10	−0.10	−0.10	−0.09	−0.09
Personal manners	−0.02	−0.02	0.09	0.09	0.10	0.10	0.15*	0.15	0.18*	0.18	0.11	0.11
Motor skills and activities	0.12	−0.14	−0.05	−0.05	−0.06	−0.08	−0.10	−0.10	−0.09	−0.09	0.02	0.02
Social skills and interactions	−0.08	−0.08	0.03	0.03	−0.02	−0.02	−0.05	−0.05	−0.02	−0.02	0.09	0.09
Body and physiologic functions	0.02	0.02	−0.03	−0.03	−0.01	−0.01	0.02	0.02	0.03	0.03	0.15	0.15
Emotion	0.05	0.05	0.04	0.04	0.08	0.08	0.03	0.03	0.02	0.02	0.17*	0.17

Values for β in bold are significant, one-tailed tests, at: *$p < 0.05$, **$p < 0.025$, ***$p < 0.005$.
[a]Approximation of the Maternal Substance Abuse Checklist, based on Coles and colleagues (2000).
[b]Finger tapper singing condition.

Analyses examining the relations between the ARAE metric and neurobehavioral outcomes yielded significant effects for 21 of the 36 outcomes (58.3%) across 8 of the 10 neurobehavioral tests. Of the 10 tests, only the CPT (Number of Hits) and Object Memory tests were not significantly related to the ARAE risk drinking metric (Table 6). The ARAE metric was related significantly to 7 of 15 subscales from the WPPSI, including predicting deficits in Arithmetic, Picture Completion, Performance IQ, and Full Scale IQ. The ARAE metric predicted fewer number correct for Symbol Digit and Digit Span, poorer Visual Motor Integration, poorer performance on 2 measures of fine motor ability (Pegboard and Finger Tapping), as well as poorer attention scores (Divided Attention). Compared to children identified as not at risk, children identified as exposed to "at-risk" prenatal alcohol are represented at substantially higher rates among those qualifying as deficient in Full Scale IQ (92.3% vs. 7.7%; $\chi^2 = 5.91$, $p < 0.001$), Arithmetic (77.8% vs. 22.2%; $\chi^2 = 6.76$, $p < 0.001$), Symbol Digit (71.4% vs. 28.6%; $\chi^2 = 6.26$, $p < 0.001$), and Digit Span (85.0% vs. 15.0%; $\chi^2 = 5.57$, $p < 0.001$). Finally, ARAE was also related to more problem behaviors indicated by the Academic and Communication/Speech scores on the PBCL.

In contrast, there were no significant relations identified between prenatal alcohol exposure and any of the neurobehavioral outcomes when using alcohol consumption across pregnancy (AADXP) as a predictor. Using peri-conceptional intake (AAD0)—the sample selection criterion—as the

predictor yielded significant prenatal alcohol-related associations in only 6 of the 36 outcomes (16.7%), significantly fewer than the 21 outcomes predicted by the ARAE metric ($\chi^2 = 11.62$, df = 1, $p < 0.001$), in 5 of 10 tests: Digit Span Forward, the Pegboard, Object Memory, Symbol Digit, and WPPSI. Also in contrast to the ARAE, which predicted deficits in almost half of the WPPSI subscales, only one, the WPPSI Maze subscale, was predicted by any individual alcohol consumption measure (Table 6). Alcohol consumption per drinking day, either across pregnancy (AADDXP) or at conception (AADD0), yielded very similar patterns of neurobehavioral dysfunction with each predicting significantly poorer performance in 8 or 9, respectively, of the 36 outcomes (22.2% or 25%), both of which were significantly fewer than what the ARAE metric predicted ($\chi^2 = 8.31$, df = 1, $p < 0.005$; $\chi^2 = 6.91$, df = 1, $p < 0.01$, respectively), in 8 of the 10 tests used (Table 6).

Maternal Substance Abuse Checklist (MSAC)

The ability of the MSAC-like checklist to predict alcohol-related effects in this sample was also examined, but this assessment was only an approximation as only 14 of the 17 indicators in the MSAC (Coles et al., 2000) were available. Significant prenatal alcohol-related effects were identified by the MSAC-like checklist in only 4 of 36 outcomes (11.1%), significantly fewer than the ARAE metric ($\chi^2 = 15.69$, df = 1, $p < 0.001$), on only 3 of 10 tests: Digit Span, Pegboard (2 outcomes), and the CPT. These results with the MSAC suggest that including other indicators of risk that are not specific to alcohol intake, or necessarily alcohol-related problems (e.g., maternal age, anemia, cigarette smoking), in an assessment may not improve sensitivity or specificity for prenatal alcohol-related neurobehavioral dysfunctions or deficits in this sample.

DISCUSSION

This study compared the ability of a dichotomous ("yes/no") metric based upon different self-reported indices of maternal "at-risk" alcohol consumption during pregnancy, as well as a previous maternal substance abuse index (MSAC; Coles et al., 2000), to predict relations between prenatal alcohol exposure and neurobehavioral outcomes in children. While half the children were selected based on a single maternal indicator of maternal "at-risk" drinking [i.e., average periconceptional drinking (AAD0) ≥1.0 oz/day], 23.1% more of the women (62.3%) were identified as "at-risk" by the dichotomous metric. The results confirmed our a priori hypothesis that a metric reflecting several maternal risk drinking measures better predicted neurobehavioral deficits or dysfunctions in a sample of 4- to 5-year-old inner-city African-American children than did any individual measure of alcohol consumption alone. The relative value of the dichotomous ARAE metric compared to other measures is demonstrated in the fact that the metric identified significantly poorer performance on up to 5 times more neurobehavioral outcomes than did the individual alcohol consumption measures—including AAD0, the sample selection criterion, or the MSAC.

All of the differences in neurobehavioral outcome significantly related to the ARAE metric are recognized to be outcomes affected by prenatal alcohol exposure (e.g., Kodituwakku, 2007; Nash et al., 2006; Spadoni et al., 2007; Vaurio et al., 2008). Only the current "at-risk" metric, and none of the individual alcohol consumption measures, nor the MSAC, was related to differences in IQ or several components of the FASD neurobehavioral "profile" including arithmetic, attention and behavior problems as assessed by the PBCL-36 (e.g., Burden et al., 2005; Jacobson, 1998; Kodituwakku, 2007; Riley et al., 2003; Streissguth et al., 1998; Vaurio et al., 2008). The PBCL, devised from children with FASD diagnoses (Streissguth et al., 1998), was predicted by the "at-risk" metric, not alcohol consumption measures alone, suggesting that this metric may be sensitive to patterns and consequences of drinking that are behaviorally teratogenic.

Uncertainties in assessing prenatal alcohol exposure via maternal self-report may explain some of the diverse findings on neurobehavioral outcome in infants, children, and teens. Decreased cognitive ability and increased behavior problems were associated with varying levels of prenatal alcohol exposure in many (Coles et al., 2002; Kable and Coles, 2004; Mattson and Riley, 1999; Nordstrom-Bailey et al., 2004; Russell et al., 1991; Uecker and Nadel, 1996) but not all studies or outcomes (Brown et al., 1991; Fried et al., 1992; Greene et al., 1990; Richardson et al., 1995; Russell et al., 1991). See Kodituwakku (2007) for a recent review. The fact that children with apparently similar levels of prenatal alcohol exposure, as assessed by self-reported measures of maternal alcohol consumption, show variable neurobehavioral effects and are or are not diagnosed with FAS (Aros et al., 2006; Vaurio et al., 2008), suggests that individual measures of maternal intake alone may not discriminate "at-risk" fetal exposure that produces behavioral and cognitive effects. FASDs are certainly also influenced by differences in vulnerability, critical periods, and individual susceptibility, yet it may be a pattern of "at-risk" drinking that is most important in predicting FASDs (Abel, 1995; Abel and Hannigan, 1995; American College of Obstetrics & Gynecology, 2006; Ernhart et al., 1987; Henderson et al., 2007; Jacobson and Jacobson, 1994, 1999; Martínez-Frías et al., 2004; May et al., 2008; NIAAA, 2005a; Olney, 2004; Sokol et al., 1986; Stratton et al., 1996; West et al., 1994). An effective measure of maternal at-risk drinking, therefore, ought to focus precisely on detecting those patterns, minimize problems in self report, and predict neurobehavioral effects in the children. The current metric was constructed to do that.

The comparison of the current "at-risk" metric with our approximation of the Maternal Substance Abuse Checklist (MSAC; Coles et al., 2000) indicated that the MSAC-like measure did not predict, in this sample, many developmental or cognitive outcomes known to be affected by prenatal

alcohol exposure (Kodituwakku, 2007), but that were predicted by the ARAE metric, and even by AAD0, AADD0, or AADDXP (Table 6). Each component of the current metric focuses on maternal drinking and consequences rather than, for example, parity, smoking or disease, and so may have relatively greater specificity for alcohol-related effects than the MSAC. Important limitations of these comparisons to the MSAC are that we did not have the information to compute the full MSAC (Table 1), and the samples, age of testing, and outcomes differed. Participants in the MSAC study were selected from a surveillance sample of low birth-weight neonates based on microcephaly, retrospectively assessed maternal "heavy episodic drinking" (≥5 drinks/occasion), or the MSAC itself, half the sample was recruited from a suburban hospital, and the outcomes were the Bayley Scales of Infant Development at 6 and 12 months of age (Coles et al., 2000).

Another limitation of this study is potentially poor generalizability. The current cohort included only low SES urban African-American women and their children. Reliability of assessments of maternal alcohol use or abuse may differ across populations (Bradley et al., 1998; Chan et al., 1993; Ewing, 1984; Nardini et al., 2006; Sokol et al., 1989). The effectiveness of the "at-risk" metric should be replicated on a larger sample and in other populations. However, the ability of this study and the metric to detect significant neurobehavioral effects in a smaller sample than frequently reported is also a strength.

The current "at-risk" drinking metric was composed of measures available in our data. We expect that different effective metrics that capture multiple aspects of risk drinking could be constructed with measures available in other research cohorts, and that could predict neurobehavioral outcomes in the children. However, the practical value of implementing the current or similar metric in the clinic remains to be determined. The extensive data collection in the research cohort that went into the ARAE metric is not practical for a normal primary care setting, but these findings suggest that effective antenatal screens should assess multiple measures of risk drinking and problems associated with drinking. At minimum, the present results indicate that clinical suspicions or positive screens ought to be followed up with rigorous assessment of drinking patterns and consequences. One value of any measure that effectively accesses maternal risk drinking during pregnancy is that fetuses at risk are also identified, affording opportunities for intervention to eliminate or reduce maternal drinking and thereby prevent or minimize FASDs. Detecting "at-risk" drinking during pregnancy—insofar as it can be eliminated or reduced—has this advantage over even a perfect biomarker of neonatal or childhood alcohol effect (cf. Cook, 2003; Kulaga et al., 2006; Ostrea et al., 2006), because pregnancy counseling could reduce the number of affected children (Anderson, et al., 2002; Stratton et al., 1996). Further, improving the definition of fetal risk maternal alcohol consumption levels could aid in the proper diagnosis of—and subsequent intervention with—affected children because all current diagnostic systems require knowledge of "significant" or "heavy" or "substantial" maternal alcohol consumption during pregnancy to diagnose the various non-FAS FASDs (Astley, 2006; Bertrand et al., 2004, 2005; Hoyme et al., 2005; Manning and Hoyme, 2007; Stratton et al., 1996).

There are no clearly defined thresholds for the effects of alcohol on embryos and fetuses (Abel, 2006; Henderson et al., 2007; Jacobson and Jacobson, 1994; Martínez-Frías et al., 2004; Sampson et al., 2000), so current standards of care and public health advise healthcare workers to carefully monitor their pregnant patients' drinking and counsel that "no amount of alcohol consumption can be considered safe during pregnancy" (American College of Obstetrics & Gynecology, 2006; Bertrand et al., 2004, 2005; Chang, 2005; NIAAA, 2000, 2004, 2005a,b; Surgeon General, 2006). Identification of fetal risk drinking during pregnancy and intervention to reduce consumption is critical for prevention of FASDs. Assessing "at-risk" drinking in pregnant women is improved by including multiple indicators of consumption and of alcohol-related negative consequences. The current metric had greater utility than individual measures of alcohol consumption in predicting neurobehavioral outcome in preschool children, although the practical value of this or similar composite metric in the clinic remains to be determined.

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