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Physical and Motor Development of Neonates/ Infants Prenatally Exposed to Drugs in Utero: A Meta-Analysis

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The purpose of this study was to investigate the role of prenatal drug exposure on birth weight, birth length, head circumference, Apgar scores, length of gestation, and motor development (Psychomotor Development Index, PDI) scores. A meta-analytic review was conducted on 56 studies published between 1979 and June 25, 1993. There were 294 effect sizes computed using the means and standard deviations reported in each study. The composite effect sizes calculated for the growth and motor development variables were (a) –.55, $p < .01$, birth weight; (b) –.74, $p < .01$, birth length; (c) –.79, $p < .01$, head circumference; (d) –.45, $p < .01$, 1-min Apgar score; (e) –.62, $p < .01$, 5-min Apgar score; (f) –.36, $p < .01$, length of gestation; (g) –.07, $p = .55$, PDI score (3 months); (h) –.35, $p < .01$, PDI score (6 months); (i) –.74, $p < .01$, PDI score (12 months); (j) –.44, $p < .01$, PDI score (18 months); and (k) –.23, $p < .01$, PDI score (24 months). The results of this investigation demonstrated that the use/abuse of illicit substances, alcohol, or both by the mother does significantly affect the physical and motor development of neonates/infants exposed in utero.

The effects of maternal substance abuse on fetal development are not a new problem. As early as 1865, adverse effects on infants from prenatal maternal drinking were reported by Dr. E. Lanceraux (Abel, 1990). Within the last decade, many factors have contributed to the increase of substance abuse; one such factor is the availability of a variety of drugs. The *National Household Survey on Drug Abuse: Main Findings 1992* (National Institute on Drug Abuse, 1995) reported that of 206 million people surveyed, 74 million people 12 years of age and older admitted to illicit drug use (nonmedical use of marijuana, hashish, cocaine, crack, inhalants, hallucinogens, PCP [phencyclidine], heroin, or psychotherapeutics) at least once in their lifetime; 23 million people admitted to illicit drug use in the past year; and 11 million people admitted to illicit drug use in the past month. Alcohol use was reported by 171 million people 12 years of age and older in their lifetime; 133

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million people reported alcohol use in the past year; and 98 million reported current use in the past month. The percentage of persons age 18 to 25 reporting drug use in their lifetime from the years 1972 to 1992 has decreased for any illicit drug use (69.9 to 51.7%) but has increased for alcohol use (81.6 to 86.3%). The percentage of persons 26 years or older admitting to drug use in their lifetime has increased from 23.0 to 36.0% for illicit drug use and from 73.2 to 88.1% for alcohol use during the years 1972 to 1992. These depressing statistics include women of childbearing age, which is why physicians, educators, and public health officials are becoming increasingly anxious about the developmental and behavioral effects of prenatal exposure to drugs and alcohol (Zuckerman & Bresnahan, 1991). So schools can adequately prepare for the increasing number of children who have been exposed to drugs while still in the womb, we need to learn how drugs affect the developing fetus.

It is clear that drug use during pregnancy affects the developing fetus; however, the long-range impact on the growing child is unclear. Decreases in birth weight, birth length, head circumference, and gestational age have been reported for infants of mothers who have abused heroin, methadone, cocaine, alcohol, and multiple substances during pregnancy (Bateman, Ng, Hansen, & Heagarty, 1993; Chasnoff, Griffith, MacGregor, Dirkes, & Burns, 1989; Chasnoff, Hatcher, Burns, & Schnoll, 1983; Golden, Sokol, Kuhnert, & Bottoms, 1982; Lifschitz, Wilson, Smith, & Desmond, 1985). Likewise, deficits in motor development and/or activity were noted when mothers abused alcohol, multiple substances, cocaine, and methadone (Chasnoff, Griffith, Freier, & Murray, 1992; Golden et al., 1982; Hans, 1989; Ioffe & Chernick, 1990; Johnson, Diano, & Rosen, 1984). Infants whose mothers abused heroin, methadone, and multiple substances displayed signs of withdrawal (irritability, tremors, hypertonicity, convulsions, hyperactivity, hypotonicity) (Chasnoff, Schnoll, Burns, & Burns, 1984; Fulroth, Phillips, & Durand, 1989; Jeremy & Hans, 1985). Finally, mothers who abused marijuana had an increased risk for delivery of an infant who was low birth weight, preterm, and/or small for gestational age (Fried, Watkinson, & Willan, 1984; Hatch & Bracken, 1986). However, controversy still exists in the literature regarding the effects of prenatal substance abuse on physical and motor development.

Studies refuting negative results from the use of drugs during pregnancy are numerous. Several researchers have reported no significant differences in birth weight, birth length, and head circumference when the mother abused alcohol (Coles, Smith, Fernhoff, & Falek, 1985; Coles, Smith, Lancaster, & Falek, 1987), multiple substances (Chasnoff et al., 1984), or cocaine (Richardson & Day, 1991). According to Little et al. (1990), the head circumferences of neonates/infants prenatally exposed to heroin were similar to those of nonexposed neonates/infants. Similarly, no significant differences were reported in the growth parameters of neonates/infants exposed prenatally to marijuana (Fried et al., 1984; Hatch & Bracken, 1986). Jeremy and Hans (1985) and Rosen and Johnson (1985) reported that in neonates/infants prenatally exposed to methadone, birth weight values were not different from those of control offspring.

Likewise, researchers have reported similar findings for the Apgar score and the length of gestation variables. No significant differences in the Apgar score were reported for neonates/infants exposed in utero to alcohol (Ioffe & Chernick, 1990), heroin (Little et al., 1990), marijuana (Graham et al., 1992), methadone (Hans, 1989), or cocaine (Graham et al., 1992) compared with offspring not ex-

posed in utero. No significant differences in length of gestation were reported for neonates/infants exposed prenatally to methadone abuse (Kaltenbach & Finnegan, 1987), marijuana abuse (Lifschitz et al., 1985), multiple substance abuse (Castro, Azen, Hobel, & Platt, 1993), alcohol abuse (Russell, Czarnecki, Cowan, McPherson, & Mudar, 1991), heroin abuse (Little et al., 1990), and cocaine abuse (Neuspiel, Hamel, Hochberg, Greene, & Campbell, 1991).

The extent to which motor development is impacted by the mother's abuse of drugs during the pregnancy is also unclear. The Bayley Scales of Mental and Motor Development can be used to measure the motor development of neonates/infants from birth to 30 months of age (Bayley, 1969). The Motor Scale (measured with the Psychomotor Development Index [PDI] scores) provides information regarding the infant's ability to perform coordinated large muscle movements and fine motor skills of the fingers and hands and measures the degree of control the infant has over his or her body. In addressing the motor development of neonates/infants prenatally exposed to alcohol, Golden et al. (1982) and Ioffe and Chernick (1990) reported significantly lower PDI scores of exposed versus nonexposed subjects, as did Chasnoff et al. (1992) with neonates/infants prenatally exposed to multiple substances. Hans (1989) and Johnson et al. (1984) agreed when they indicated that PDI scores of offspring exposed to methadone were below PDI scores of nonexposed subjects. However, Fried and Watkinson (1988) reported no differences in the PDI scores between subjects exposed to alcohol prenatally and subjects not exposed. Likewise, no differences were reported between PDI scores of neonates/infants exposed to multiple substances (van Baar, 1990), cocaine (Graham et al., 1992), or marijuana (Fried & Watkinson, 1988).

It is clear that significant discrepancies exist within the literature as to the effects of substance abuse on specific growth measures and motor development of neonates/infants exposed in utero. Until the literature is organized and scrutinized for differences, confusion about the disparities of findings will continue. Thus, the purpose of this study was to organize and analyze the existing literature so that a conclusion could be drawn regarding the effect of substance abuse on the development of the young child. Once the types and extent of delays are identified, focus can be turned toward whether there is a need to design intervention programs to overcome significant developmental delays that may impact the child's ability to learn and benefit from educational experiences (Struthers & Hansen, 1992).

Meta-analysis was used to examine the effects of prenatal substance abuse on the variables of birth weight, birth length, head circumference, Apgar scores, gestational age, and Bayley Motor Developmental Index scores (PDI) in neonates/infants exposed in utero. Meta-analysis, a term introduced by Glass (1976), has two advantages over a traditional literature review: (a) The meta-analysis provides a set of procedures for decisions made during a literature review, and (b) it provides a quantitative method for data analysis (Thomas & French, 1986).

Method

Literature Search Procedures

We conducted on-line computer searches of PSYCHLIT and Medline to locate published research concerning the effects of prenatal substance abuse on birth measures and motor development. The key words used to locate articles in

PSYCHLIT were *drug abuse, preschool age children, motor development, neonates, birth weight, prenatal development, alcohol abuse, cocaine, marijuana, drug usage, fetal alcohol syndrome, physical development,* and *prenatal exposure.* Key words used in Medline included *cocaine, prenatal, substance abuse, alcoholism, birth weight, prenatal exposure delayed effects, pregnancy outcome,* and *child-preschool.* After the articles isolated in the PSYCHLIT and Medline searches were obtained, the references of each article were examined for related articles not identified in the computer searches.

Additionally, a weekly search of *Current Contents* was conducted. *Current Contents* is an index of all articles published during the preceding week in the social and behavioral sciences. The headings used to locate the current week's articles were *prenatal, substance abuse, cocaine,* and *alcohol.* Similarly, a manual search of the following journals was performed to locate articles not previously identified: *American Journal of Obstetrics and Gynecology, Seminars in Perinatology, Obstetrics and Gynecology,* and *Journal of Substance Abuse. Dissertation Abstracts International* was reviewed to locate relevant dissertations. Key words used for the review were *prenatal* and *substance abuse.*

Studies were required to meet the following criteria for inclusion in this meta-analysis: (a) The mother must have been exposed (used substance even once during pregnancy) to illicit substances, alcohol, or both during any or all trimesters of pregnancy as determined by a drug history or urine test, (b) the investigators must have utilized control groups (46% of the studies used in this meta-analysis had control groups matched for psycho/social variables), (c) the investigators must have used means and standard deviations in their reported outcomes, and (d) the articles must have been published between 1979 and June 25, 1993.

Coding and Classifying Variables

According to the meta-analysis technique, each study included was coded for substantive features and methodological features. We determined these features after carefully reading and evaluating the selected studies for characteristics that could possibly affect the interaction between prenatal substance abuse and infant growth and motor development. The substantive features included birth weight, birth length, head circumference, Apgar score, length of gestation, and Bayley PDI score. The methodological features were the type of substance abused and the method of identification for substance abuse. The types of substances abused by the mother were coded as marijuana, heroin, methadone, alcohol, cocaine, or multiple substances (use of more than one illicit substance, alcohol, or both as reported through a urinalysis or self-report by the mother). The method of identification for substance abuse was coded as self-reported, urinalysis, or a combination of both. Methods of self-report ranged from the mothers participating in a structured interview session administered by a trained interviewer to the mothers completing a self-administered questionnaire. Both procedures attempted to address the general pregnancy/medical status as well as behaviors/patterns of substance abuse of the mothers.

In a number of the studies used in this meta-analysis, the subjects (mother and infant) were recruited through their enrollment in programs specifically addressing substance abuse (e.g., methadone maintenance programs, perinatal addiction programs). Additionally, the subjects used in the studies in this meta-analysis may have volunteered (after being informed by an obstetrician or the media) or may have been

identified as a result of negative urine tests, or both. Interestingly, only 8 of the 56 studies used in this investigation used a procedure called meconium staining. The result of this procedure is the presence of meconium in the amniotic fluid, which can be an indicator of fetal distress that may occur as a result of substance abuse.

Additionally, demographic variables of maternal age and ethnicity were recorded in an attempt to clarify the results of the initial studies used in this meta-analysis. A number of the research studies used in this investigation did not report demographic data (e.g., maternal age, ethnicity) and did not report other information that may be useful in determining the effect of prenatal substance abuse on infant growth and motor development (e.g., amount of substance abused, duration of substance abuse, extent of prenatal care received by mother).

Statistical Analysis

Data analysis techniques were performed on the studies included in this meta-analysis. The analysis steps included the conversion of the studies' summary statistics to effect sizes (ESs), the computation of a composite effect size (Δ), and the use of model testing, outlier diagnosis, or both to attempt to explain effect size variability (Johnson, 1989).

The means, standard deviations, and numbers of subjects were used to convert the summary statistics reported in the meta-analysis studies to ESs. An effect size was calculated with the following formula: $ES = (M_E - M_C)/s_{pooled}$, where M_E is the mean for the experimental/treatment group, M_C is the mean for the control group, and s_{pooled} is the pooled standard deviation. The pooled standard deviation is calculated by the following formula: $s_{pooled} = \{[(n_E - 1)(s_E)^2 + (n_C - 1)(s_C)^2]/[n_E + n_C - 2]\}^{1/2}$, where n_E and n_C are the number of observations in the experimental and control groups, respectively, and s_E and s_C are the standard deviations for the experimental and control groups, respectively (Johnson, 1989, p. 101).

In determining the composite effect size for the meta-analysis, an unbiased estimate of the effect size (Δ) was calculated to account for small sample size (Thomas & Nelson, 1990, p. 254). According to Cohen (1988), the mean effect size can be described as having a small ($\Delta = .2$), medium ($\Delta = .5$), and large ($\Delta = .8$) effect. In this investigation, the following ranges were utilized to determine the strength of the effect sizes: (a) small effect, .10–.39; (b) medium effect, .40–.69; or (c) large effect, .70 and above. A 95% confidence interval (CI) was then computed for this mean to test for significance. There is no significant relationship between the independent and dependent variables if the CI includes zero.

Homogeneity of the ESs was evaluated to determine if the studies could be represented by a single effect size (Hedges & Olkin, 1985). If homogeneity is reported among the effect sizes, the procedures of model testing, diagnosis of outliers, or both to account for variability need not be performed because the studies utilized in the meta-analysis report similar results. However, if the effect sizes are heterogeneous in nature, the variance in the effect sizes needs to be identified through model testing, outlier diagnosis, or both (Johnson, 1989).

Johnson (1989) indicated that model testing consists of utilizing the characteristics/qualities of the studies in the meta-analysis to account for variance in the heterogeneity of the effect sizes. In this meta-analysis, categorical model testing was utilized. Categorical testing is comparable to analyses of variance and may indicate that heterogeneous effect sizes are homogeneous within the subgroups es-

tablished by dividing studies into classes based on study characteristics/qualities. Categorical testing may also indicate that these classes differ in the mean effect size produced. The results of the categorical testing depend on the methodological features specifically coded for under each substantive feature (birth weight, birth length, head circumference, Apgar score, length of gestation, PDI score). After we carefully read and evaluated the selected studies in this meta-analysis, the "model" characteristics of (a) type of substance abused and (b) method of identification for substance abuse were selected as features most likely to provide the most information regarding the possible interaction between prenatal substance abuse and infant growth and motor development. Not all of the model classes for each methodological feature had subjects in every particular class (refer to Figures 1–11).

Results

Literature Search

Of the 216 studies evaluated, only 56 met the criteria for inclusion in this analysis. Reasons for rejecting 160 studies were as follows. Twenty-six studies were excluded because they did not have a control group. The specific type of drug (i.e., tobacco) abused during pregnancy disqualified five studies. Sixteen studies did

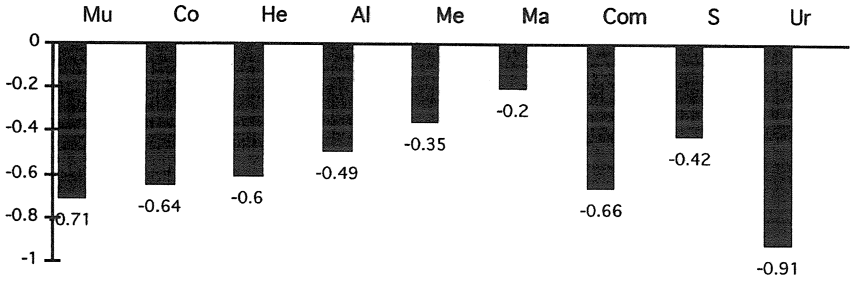

Figure 1 — Effect sizes of model testing (birth weight). Mu = multiple substances (*n* = 16); Co = cocaine (*n* = 24); He = heroin (*n* = 7); Al = alcohol (*n* = 15); Me = methadone (*n* = 13); Ma = marijuana (*n* = 6); Com = combination (*n* = 38); S = self-report (*n* = 38); Ur = urinalysis (*n* = 5).

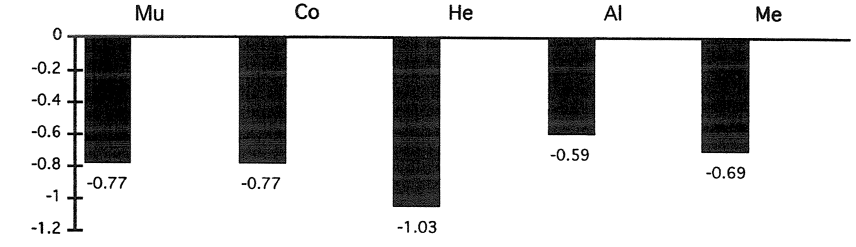

Figure 2 — Effect sizes of model testing (birth length). Mu = multiple substances (*n* = 8); Co = cocaine (*n* = 13); He = heroin (*n* = 4); Al = alcohol (*n* = 11); Me = methadone (*n* = 7).

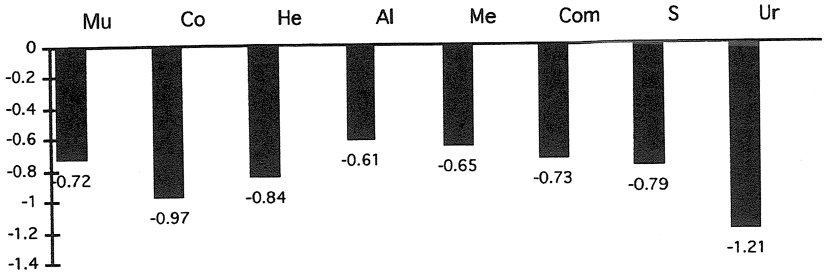

Figure 3 — Effect sizes of model testing (head circumference). Mu = multiple substances (n = 9); Co = cocaine (n = 16); He = heroin (n = 5); Al = alcohol (n = 11); Me = methadone (n = 8); Com = combination (n = 26); S = self-report (n = 19); Ur = urinalysis (n = 4).

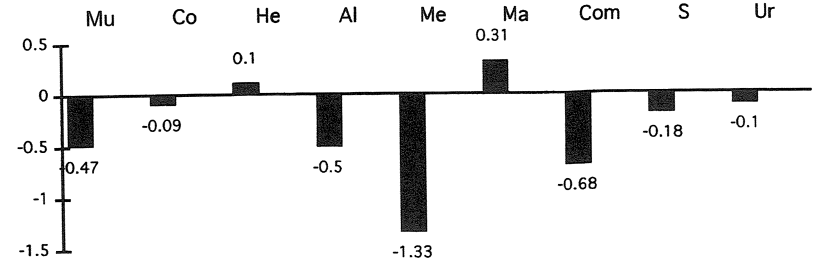

Figure 4 — Effect sizes of model testing (1-min Apgar). Mu = multiple substances (n = 2); Co = cocaine (n = 3); He = heroin (n = 2); Al = alcohol (n = 1); Me = methadone (n = 5); Ma = marijuana (n = 1); Com = combination (n = 7); S = self-report (n = 1); Ur = urinalysis (n = 6).

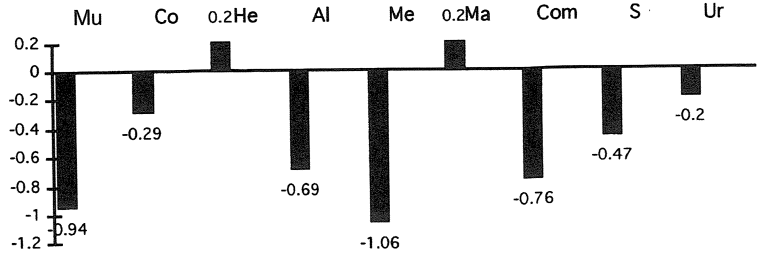

Figure 5 — Effect sizes of model testing (5-min Apgar). Mu = multiple substances (n = 2); Co = cocaine (n = 5); He = heroin (n = 1); Al = alcohol (n = 6); Me = methadone (n = 5); Ma = marijuana (n = 1); Com = combination (n = 9); S = self-report (n = 10); Ur = urinalysis (n = 1).

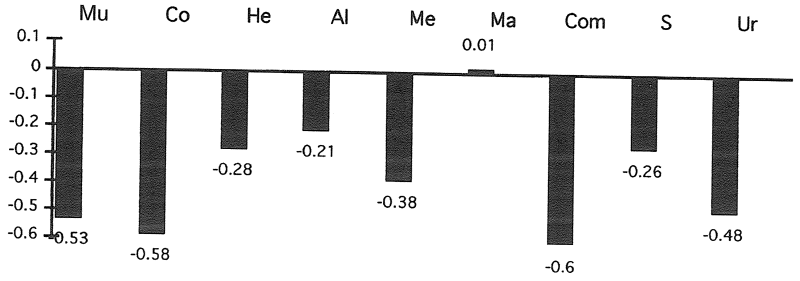

Figure 6 — Effect sizes of model testing (gestational age). Mu = multiple substances (n = 9); Co = cocaine (n = 15); He = heroin (n = 5); Al = alcohol (n = 13); Me = methadone (n = 4); Ma = marijuana (n = 5); Com = combination (n = 15); S = self-report (n = 32); Ur = urinalysis (n = 4).

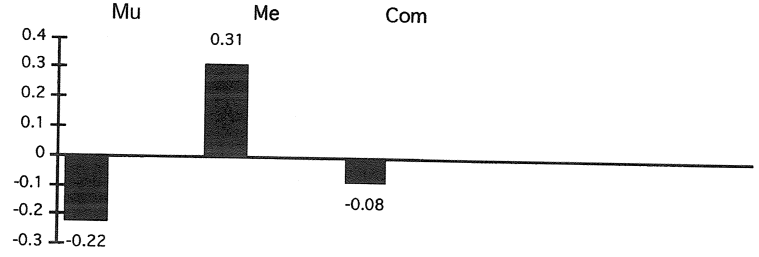

Figure 7 — Effect sizes of model testing (3-month PDI). Mu = multiple substances (n = 3); Me = methadone (n = 1); Com = combination (n = 4).

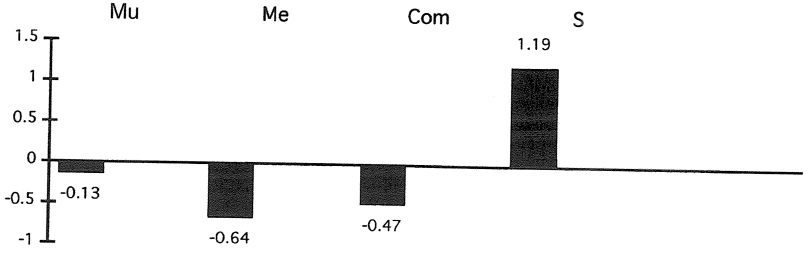

Figure 8 — Effect sizes of model testing (6-month PDI). Mu = multiple substances (n = 4); Me = methadone (n = 3); Com = combination (n = 6); S = self-report (n = 1).

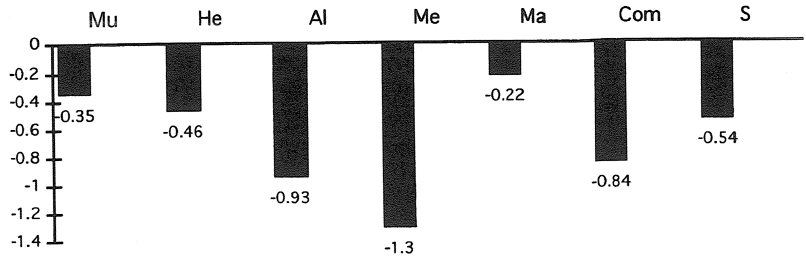

Figure 9 — Effect sizes of model testing (12-month PDI). Mu = multiple substances (*n* = 4); He = heroin (*n* = 1); Al = alcohol (*n* = 2); Me = methadone (*n* = 4); Ma = marijuana (*n* = 1); Com = combination (*n* = 8); S = self-report (*n* = 4).

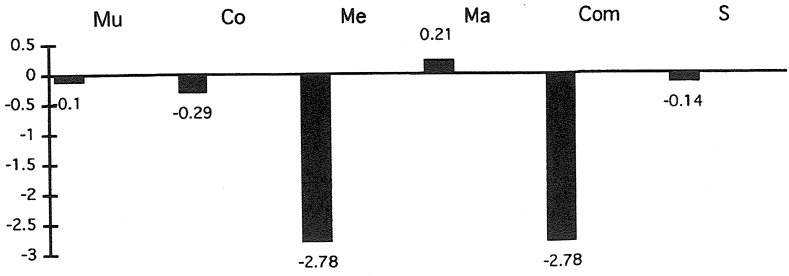

Figure 10 — Effect sizes of model testing (18-month PDI). Mu = multiple substances (*n* = 1); Co = cocaine (*n* = 1); Me = methadone (*n* = 1); Ma = marijuana (*n* = 1); Com = combination (*n* = 1); S = self-report (*n* = 3).

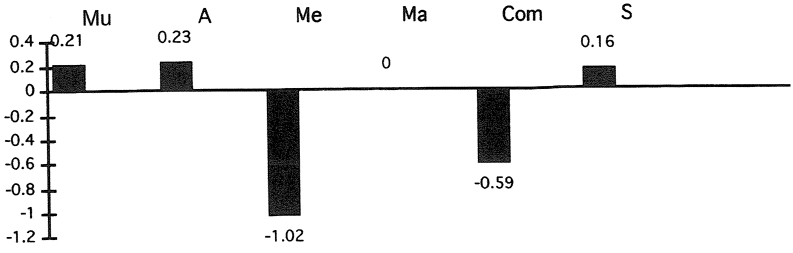

Figure 11 — Effect sizes of model testing (24-month PDI). Mu = multiple substances (*n* = 4); Al = alcohol (*n* = 1); Me = methadone (*n* = 3); Ma = marijuana (*n* = 1); Com = combination (*n* = 6); S = self-report (*n* = 3).

not provide mean and standard deviation values that could be extracted for inclusion in this meta-analysis. Thirty-nine studies examined the influence of prenatal substance exposure but failed to report infant data. Animals were utilized in two studies, thus excluding the articles from this study. Seventy-two studies were rejected because they were reviews and opinion papers.

Overall Analysis

A summary of study characteristics is found in Table 1. From the total of 56 studies, 294 effect sizes were yielded. The demographic characteristics of the mothers (ethnicity and maternal age at delivery) (refer to Table 2) provide background information regarding the subjects used in the studies that may aid in interpretation of the data.

The findings of this study can be summarized as follows:

1. Prenatal substance exposure did have a significant effect on the birth weights of neonates/infants ($\Delta = -.55$, $p < .01$) as represented by the 95% CI not including zero (–.58/–.52). The birth weights of infants exposed prenatally to drugs were lower than the birth weights of nonexposed infants.

2. A significant decrease in birth lengths of the neonates/infants was measured as a result of prenatal exposure to drugs ($\Delta = -.74$, $p < .01$) as described by the 95% CI not including zero (–.79/–.68).

3. Prenatal exposure to drugs had a significant effect on head circumferences of neonates/infants ($\Delta = -.79$, $p < .01$) as described by the 95% CI not including zero (–.84/–.73). Neonates/infants exposed in utero had smaller head circumference measurements than neonates/infants not exposed in utero.

4. There was a significant decrease in the 1-min Apgar scores ($\Delta = -.45$, $p < .01$) and the 5-min Apgar scores ($\Delta = -.62$, $p < .01$) of the neonates/infants as a result of prenatal substance abuse as represented by the 95% CI not including zero (–.56/–.35 and –.71/–.52, respectively).

Table 1 Study Characteristics

Variable	Total (*N*)	Experimental (*N*)	Control (*N*)
Birth weight	46,577	4,947	41,630
Birth length	4,833	1,933	2,900
Head circumference	9,234	2,212	7,022
1-min Apgar	1,244	605	639
5-min Apgar	1,492	725	767
Gestational age	33,385	3,090	30,295
3-month PDI	244	108	136
6-month PDI	375	176	199
12-month PDI	864	272	592
18-month PDI	222	106	116
24-month PDI	586	152	434

Note. *N* = number of subjects; total = experimental and control *N* combined.

Table 2 Demographic Characteristics of the Mothers

	Experimental	Control
Age (years)	26.5	25.3
Ethnicity (*N*)		
White	27.3	253.2
Hispanic	13.4	92.7
Black	33.7	106.7
Nonblack	18.2	37.0
Nonwhite	30.0	185.0
Other	12.2	65.1

Note. Age (years) = mean age of mothers at time of delivery; ethnicity (*N*) = data reported as means.

5. Gestational age in the exposed infants was significantly affected ($\Delta = -.36$, $p < .01$) by prenatal substance abuse as represented by the 95% CI not including zero (–.40/–.31). Infants exposed prenatally demonstrated shorter lengths of gestation than infants not exposed.

6. The PDI score measured at 3 months was not affected significantly by prenatal substance abuse as described by the 95% CI including zero (–.33/+.18). However, when measured at 6, 12, 18, and 24 months, the PDI scores of the neonates/infants were significantly affected by exposure to drugs in utero ($\Delta = -.35$, $p < .01$; $\Delta = -.74$, $p < .01$; $\Delta = -.44$, $p < .01$; $\Delta = -.23$, $p < .01$; respectively) as demonstrated by the 95% CI not including zero (–.56/–.13,–.90/–.56, –.69/–.19, –.45/–.02, respectively). The PDI scores measured at 6, 12, 18, and 24 months were lower in infants exposed in utero to drugs than in nonexposed infants.

Analysis of Categorical Model Testing

In addition, this meta-analysis revealed that the outcomes of the studies used in the investigation were very heterogeneous (significant Q_{wi} statistics: birth weight = 978.5, $p = .00$; birth length = 101.7, $p = .00$; head circumference = 355.2, $p = .00$; 1-min Apgar = 451.2, $p = .00$; 5-min Apgar = 421.2, $p = .00$; length of gestation = 519.2, $p = .00$; PDI (3 month) = 10.0, $p = .02$; PDI (6 month) = 17.5, $p = .01$; PDI (12 month) = 121.1, $p = .00$; PDI (18 month) = 46.0, $p = .00$; PDI (24 month) = 67.3, $p = .00$). As a result of this heterogeneity, categorical model testing was performed in an attempt to account for this variance. The type of substance abused (marijuana, heroin, methadone, alcohol, cocaine, multiple substances) and the method of identification for substance abuse (self-report, urinalysis, combination of self-report and urinalysis) were selected a priori as moderator variables thought to influence the growth and motor development of infants exposed in utero to drugs.

The effect sizes of the model testing are reported in Figures 1–11. These figures simply highlight the effect sizes generated for each model characteristic (type of substance abused and method of identification for substance abuse) for the dependent variables under study. The ranges for the effect sizes utilized in this

investigation were (a) small effect, .1 to .39; (b) medium effect, .40 to .69; and (c) large effect, .7 and above. As indicated by a significant Q_B statistic, the type of substance abuse model fit the effect sizes for the variables of birth weight (Q_B = 98.35, $p < .01$), birth length ($Q_B = 10.35$, $p = .03$), head circumference ($Q_B = 25.89$, $p < .01$), 1-min Apgar ($Q_B = 89.93$, $p < .01$), 5-min Apgar ($Q_B = 63.98$, $p < .01$), length of gestation ($Q_B = 111.37$, $p < .01$), and PDI scores at 6 ($Q_B = 5.42$, $p = .02$), 12 ($Q_B = 25.99$, $p < .01$), 18 ($Q_B = 46.02$, $p < .01$), and 24 ($Q_B = 25.89$, $p < .01$) months. Likewise, the method of identification for substance abuse model adequately fit the effect sizes for the variables of birth weight ($Q_B = 67.39$, $p < .01$), head circumference ($Q_B = 18.64$, $p < .01$), 1-min Apgar ($Q_B = 22.67$, $p < .01$), 5-min Apgar ($Q_B = 10.52$, $p < .01$), length of gestation ($Q_B = 48.47$, $p < .01$), and PDI scores at 6 ($Q_B = 5.44$, $p = .02$), 18 ($Q_B = 43.86$, $p < .01$), and 24 ($Q_B = 11.32$, $p < .01$) months. Generally, the results of the model testing overall accounted for the variance of the studies used in this investigation.

Discussion

Why, then, does such discrepancy exist in the literature on this topic? Discussing three issues or areas of concern may help to explain this discrepancy. The areas include the weaknesses of the studies that were utilized in this meta-analysis, the limitations of this investigation, and possible areas of future study.

Weaknesses of Studies

Studies used in this investigation needed to meet inclusion criteria. One area of concern highlighted in this study was the type of control groups. Even though all 56 studies had control groups, only 26 of the studies (46%) utilized matched control groups. The groups were matched on such psycho/social variables as ethnicity, maternal age, socioeconomic status, tobacco/alcohol use, marital status, obstetric history, and pregnancy risk factors. Extreme variability existed in the studies, because of the 46% that did match the control group to the study group, not all matched with all the same psycho/social variables. It could be these variables (not substance abuse) that impacted the growth and motor development of the infants/neonates prenatally exposed.

A second area of concern was the way in which the subjects (mothers and infants/neonates) were included in the various investigations. Some participants were included based on their enrollment in programs designed for prenatal/perinatal addiction or methadone maintenance. Other subjects may have also volunteered after being informed of the research by their obstetrician, the media, or both. A question of concern is, Were the subjects used in these studies of a representative population of substance abusers? How many of these women received adequate prenatal care or even received prenatal care at all? Again, due to the variability in methods of subject selection, was the growth and motor development of the infants influenced by something other than the prenatal substance abuse?

Limitations

This study had four limitations: (a) Studies were analyzed that used subjects (infants/neonates) exposed to illicit substances, alcohol, or both in utero, (b) only

published studies from 1979 to June 25, 1993 were included in this investigation, (c) this study was dependent on the findings reported by researchers of the published investigations, and (d) there was no attempt made to critique the quality of research designs of the studies used in this meta-analysis. Other concerns must be addressed in an attempt to interpret the findings of this investigation.

For example, isolating the type of substance the mother abused and then determining if that particular substance adversely affected the neonate/infant can be difficult. According to Bandstra and Burkett (1991), "Polysubstance exposure, usually varying combinations of cocaine, tobacco, alcohol, and marijuana, is the rule among pregnant substance abusers" (p. 296); therefore, the "true" effects of a particular drug on infant development may not be discernible. When we further evaluated the results of the model testing in the present study, examination of the Q_{wi} statistic revealed a lack of within-class homogeneity. Heterogeneity among the classes within this model was exhibited for the variables of birth weight, head circumference, and length of gestation. Simply stated, the subjects identified as cocaine users, for example, did not come from a homogeneous sample. Although the overall model of the type of drug abused adequately fit the effect sizes for each of these three variables, it is quite possible that the heterogeneity in the effect sizes within the model could be a result of this "multiple substance abuse" speculation. It would be of benefit to know if the subjects in the studies reporting only cocaine abuse, for example, used any other drugs during pregnancy.

Similarly, as shown by the data in Table 3 for the method of identification of substance abuse model, all three classes produced large or medium negative effects on the dependent variables. The combination class seemed to have the largest impact, affecting 9 out of the 11 variables. Generally, the sample sizes for the dependent variables for this class were larger in comparison to sample sizes in the self-report and urinalysis classes. The 18-month PDI score in the combination class was the only variable with a sample size less than 5 ($n = 1$). An important finding from these data would be the use of more than one method in the identification of substance abuse in pregnant women.

Unreliability of mothers' self-report of their own substance abuse has been well documented (Slutsker, 1992; Weston, Ivins, Zuckerman, Jones, & Lopez, 1989). The limited usefulness of the urinalysis to assess substance abuse was also noted by Slutsker (1992). For example, it is possible to detect the primary metabolite of cocaine up to 72 hr after the last dose using chromatographic techniques and for 144 hr after the last dose utilizing radioimmunoassay. Therefore, if cocaine use occurred more than 7 days before testing, for example, the urinalysis may provide a negative test for the metabolite (Slutsker, 1992). This lack of identification of substance abuse in the mother could possibly prevent the neonate/infant from receiving appropriate medical care upon delivery and/or future interventions, if needed. Although model testing did account for the variance in initial effect sizes, the model components of self-reporting, urinalysis, and/or a combination approach to identify substance abuse may not be clinically accountable.

Future Research

In addition to facing the above-mentioned issues, investigators will continue to struggle methodologically with research in prenatal substance abuse. A more prac-

Table 3 Model Testing Summary

	IVs having large or medium effects on DVs								
	Al	Co	He	Ma	Me	Mu	Com	S	Ur
Birth weight	–.49	–.64	–.60	–.71	–.66	–.42	–.91	–.99	–.99
Birth length	–.59	–.77	–1.03		–.69	–.77			
Head circumference	–.61	–.97	–.84		–.65	–.72	–.73	–.79	–1.21
1-min Apgar score	–.50				–1.33	–.47	–.68		
5-min Apgar score	–.68				–1.06	–.94	–.76	–.47	
Gestational age		–.58				–.53	–.60		–.48
3-month PDI[a]									
6-month PDI					–.64		–.47		
12-month PDI	–.93		–.46		–1.30		–.84	–.54	
18-month PDI					–2.78		–2.78		
24-month PDI					–1.02		–.59		

Note. IVs = independent variables; DVs = dependent variables; Al = alcohol; Co = cocaine; He = heroin; Ma = marijuana; Me = methadone; Mu = multiple substances; Com = combination of both methods; S = self-report; U = urinalysis. Medium effect size = .4–.69. Large effect size = .7 and above.

[a]No medium or large effect sizes produced.

tical finding of this meta-analysis might be the importance of finding more concise methods of gathering data on women who abuse drugs during pregnancy. Other methodological concerns such as the amount of the substances abused, the time period during pregnancy when the substances were abused, or the amount and kind of prenatal care received by the mother might provide a more complete picture concerning the outcome of prenatal substance exposure on infant development.

Future areas of research on the topic of prenatal exposure to drugs may include the following:

1. Development of methods to specifically identify which drugs the infant was exposed to in utero.
2. The use of meconium staining, hair analysis, or both as more advanced methods of identification for substance abuse.
3. The identification of other moderator variables, such as prenatal care and nutritional habits of the mother, which might impact the growth and motor development of the infant.
4. The identification of longitudinal effects of prenatal substance abuse on the cognitive, physical, and social development of children (3 years of age and older).

This meta-analytic review of the literature revealed that prenatal exposure to illicit substances, alcohol, or both negatively influences infant growth and motor

development. More specifically, the use/abuse of illicit substances, alcohol, or both by the mother affects the birth weight, birth length, head circumference, 1-min Apgar score, 5-min Apgar score, length of gestation, and PDI score measured at 6, 12, 18, and 24 months of neonates/infants exposed in utero. However, this finding should be interpreted with caution. Due to the numerous methodological concerns raised in this investigation, further research is highly recommended to determine the impact of prenatal drug exposure on growth and motor development.

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(References marked with an asterisk indicate studies included in the meta-analysis.)

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