Objective: To examine the associations between sleep problems and prenatal exposure to cocaine, opiates, marijuana, alcohol, and nicotine in children aged 1 month to 12 years.

Results: Of the 5 substances, prenatal nicotine exposure was the only unique predictor of sleep problems ($B = 0.074$, $R^2$ change = 0.008, $P = .01$), with adjustment for covariates, including socioeconomic status, marital status, physical abuse, prenatal medical care, and postnatal cigarette smoke exposure.

Conclusions: Prenatal exposure to nicotine was positively associated with children's sleep problems persisting throughout the first 12 years of life. Targeting of this group of children for educational and behavioral efforts to prevent and treat sleep problems is merited given that good sleep may serve as a protective factor for other developmental outcomes.

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Sleep problems in children are associated with daytime impairment, including altered psychomotor performance,1 behavioral disturbance,2 sleepiness,3,4 decreased physical activity and social interest,5 memory and learning deficits,5 and substance use.6 The role of sleep in the development of children with prenatal drug exposure, however, is not well understood. Sleep studies with prenatally exposed children have been limited almost entirely to infancy. Observable decrements in sleep duration and continuity and in sleep-state organization have been found in infants with prenatal cocaine exposure7-10 and, more recently, in infants with prenatal exposure to alcohol11 and nicotine.12 In addition, differences in electroencephalographic sleep patterns between exposed and unexposed infants have been demonstrated in studies of prenatal exposure to opiates,13 alcohol,14 and nicotine.15

Until recently, there were no longitudinal sleep studies of prenatal exposure to cocaine, opiates, alcohol, or nicotine. One study in 3-year-old children found more disrupted sleep to be associated with prenatal exposure to marijuana.16 Furthermore, an association between sleep problems through 9 years of age and prenatal nicotine exposure has been documented in a small Maternal Lifestyle Study sample ($n = 139$),17 meriting a larger study with better control of covariates and more power to investigate level of prenatal exposure. The aim of the current study, therefore, was to investigate the effects of prenatal exposure (including level of exposure) to cocaine, opiates, marijuana, nicotine, and alcohol on sleep problems over time (1 month to 12 years) in a large sample of children ($n = 808$).
STUDY METHODS

The Maternal Lifestyle Study is a multisite longitudinal investigation of the developmental effects of prenatal exposure to cocaine and other drugs.18-20 The Maternal Lifestyle Study enrolled 1388 children at birth from 1993 to 1995 and was approved by an appropriate institutional review board at each of its 4 sites (Wayne State University, Detroit, Michigan; University of Tennessee at Memphis, Memphis, Tennessee; University of Miami, Miami, Florida; and Brown University, Providence, Rhode Island).21 Confidentiality regarding the participants’ drug use was assured through each center’s National Institute on Drug Abuse certificate of confidentiality.

Mothers were recruited in the hospital after delivery and informed consent was obtained at that time. All women delivering very-low-birth-weight newborns (ie, 301-1500 g) were approached to maximize likelihood of recruiting participants who either had prenatal cocaine exposure or were appropriate group-matched controls. During normal business hours, other mothers (ie, those delivering newborns <1500 g) were also approached. Mothers were eligible if they were aged 18 years or older and did not have psychiatric disorders, developmental delays, or language barriers. Neonates were eligible if they were inborn, likely to survive, a singleton, and were born before 43 weeks’ gestation. Mother-infant dyads were excluded from the study, starting with the 1-month visit, if the infant had a chromosomal abnormality or toxoplasmosis, rubella, cytomegalovirus, herpes, or syphilis infection or if the mother planned to move out of the catchment area. Comparison participants were matched on ethnicity (black, white, Hispanic, and other), sex, and gestational age. Another match was generated when an infant in the comparison group did not attend the 1-month visit. It was not always possible, however, to replace exposed infants who withdrew, which yielded uneven groups: 638 in the cocaine or opiate–exposed group and 730 in the comparison group.

PARTICIPANTS

Mothers were assigned to the cocaine/opiate exposure group based on either maternal report and/or meconium toxicology with gas chromatography–mass spectroscopy assay confirmation. To be assigned to the comparison group, participants who denied cocaine or opiate use during pregnancy also had to have negative meconium toxicology results. The same procedure was followed for identification of marijuana exposure. Alcohol and tobacco use were assessed by maternal report alone. Level (ie, amount) of prenatal exposure to each of those 5 substances (cocaine, opiates, marijuana, alcohol, and nicotine) was determined at the 1-month visit using the Maternal Interview of Substance Use, which provides information about the frequency (eg, number of times used cocaine each week) and quantity (ie, number of cigarettes, joints, or ounces of alcohol used or consumed each day) of substance use during pregnancy. To be eligible for the current study, participants must have completed more than half of all the sleep measures administered from 1 month to 12 years. Eight hundred eighty participants were eligible (374 exposed to cocaine and/or opiates and 434 comparison subjects), which is the final sample for this study.

DEMOGRAPHIC AND MATERNAL MEASURES

At the 1-month visit, self-report information about prenatal care, maternal age, marital status, education level, socioeconomic status (SES), and poverty status was gathered. The Caretaker Inventory of Substance Use was used at yearly visits to assess level of postnatal use of each of the 5 substances since pregnancy. Furthermore, questionnaires assessed the number of caretaker changes (number of times the child changed caregivers during the 12-year period); child abuse (yes or no each year, defined by medical examination findings suggestive of physical or sexual abuse or removal of the child from the home owing to suspicion or verification of physical or sexual abuse); and domestic violence, including physical and sexual abuse experienced by the caretaker (yes or no, years 5-12).

SLEEP MEASURES

The sleep problems index was created to measure global sleep difficulties, particularly difficulties falling or staying sleep, in our sample across the first 12 years of life using sleep items on the 4 pediatric questionnaires described below. All items within each period (1 month to 4 years, 3-8 years, and 9-12 years) were summed for 3 age-relative indexes of sleep problems. We then computed a total sleep problems index summing all 45 items from 1 month to 12 years. Our sleep problems indexes were prorated for missing items. That is, we accounted for missing data by multiplying the mean of the items that were present by the total number of possible items. Other studies have created a composite score from questionnaires, such as the Child Behavior Checklist, with adequate internal consistency (α=0.64).22 The Cronbach α for the sleep problems index at each period for our study was 0.64, 0.74, and 0.8, respectively. The Cronbach α for the overall sleep problems index was 0.88.

The Child Behavior Checklist was administered at the 3-, 5-, 7-, 9-, and 11-year assessments. This standardized parent-reported questionnaire identifies behavioral and emotional problems of children during the past 6 months and includes the following sleep-related items: having problems sleeping at night, having trouble getting to sleep, talking in one’s sleep, crying in one’s sleep, sleepwalking, waking up often at night, and sleeping less than or more than most. The child was assigned 1 point for each item the parent endorsed. The Child Health and Illness Profile was administered at years 10 to 12. This validated questionnaire assesses children’s health and well-being and includes 1 item assessing “trouble falling asleep.” If endorsed, the child was assigned 1 point. The child was also assigned 1 point if the parent endorsed “trouble sleeping” on the Pediatric Symptom Checklist, which was administered at years 8 to 12. The Pediatric Symptom Checklist is a 35-item psychosocial screener for cognitive, behavioral, and emotional problems.23 A general health questionnaire administered yearly contained the following sleep items: problems with sleeping, falling asleep at an unreasonable time, waking at night and requiring attention, being medicated for insomnia, and sleep disorder diagnosis. The child was assigned 1 point for each item the parent endorsed.

STATISTICAL ANALYSIS

A χ² test or t test was used to compare sample characteristics of attrition (Table 1) and exposure (Table 2) groups. Analysis of variance was used to compare the cocaine or opiate exposure group to the comparison group on the overall sleep problems index.

A 2-step approach was used to determine which of the 5 substances (cocaine, opiates, marijuana, alcohol, and/or nicotine) were significant predictors of sleep problems. In step 1, all 5 substances were entered together in a regression model to determine which of the substances reached significance (P <.05), which would suggest an association with sleep problems un-
When comparing participants in the 12-year follow-up (those included in this study) with those not in the 12-year follow-up (Table 1), children in the 12-year follow-up were more likely to be a racial minority (African American, Hispanic, or other) and had more caretaker changes over time. Mothers or caregivers in this study were less likely to use marijuana prenatally and more likely to use cocaine, marijuana, and/or alcohol postnatally. There were no significant differences on newborn medical characteristics (prematurity, birth weight, length at birth, head circumference at birth, and sex). There were no significant differences in level (amount) of postnatal substance use (cocaine, opiates, marijuana, alcohol, or nicotine) among the 2 attrition groups.

There were also differences between the 2 exposure groups (Table 2). Compared with mothers who did not use cocaine during pregnancy, mothers in the exposed group were more likely to be of a low SES, more likely to be older, less likely to be married, less likely to have at least a high school education, and less likely to have had any prenatal care. Furthermore, mothers and caregivers in the exposed group were more likely to use substances (cocaine, opiates, marijuana, alcohol, or nicotine) both prenatally and postnatally. Children in the exposed group were more likely to have been physically or sexually abused and had more caretaker changes over time than children in the comparison group.

In the unadjusted analysis among the 5 substances, prenatal nicotine exposure was the only significant predictor of sleep problems ($\beta = 0.168$, $P < .001$). Importantly, multicollinearity was not a problem, as evidenced by tolerance remaining above 0.7 and the variance inflation factor remaining between 1 and 2. None of the prenatal exposure variables were highly correlated with each other (all $r < 0.4$). When adjusted for covariates (SES, marital status, physical or sexual abuse, prenatal care, clinic site, and postnatal cigarette smoke exposure), the effect of prenatal nicotine exposure predicting more sleep problems on the sleep problems index was still statistically significantly (unstandardized coefficient [$B$] = 0.074, $R^2 = 0.067$, $R^2$ change = 0.008, $P = .01$). Higher levels of prenatal exposure to nicotine predicted more sleep problems. Specifically, after controlling for covariates, each additional cigarette smoked per day during a pregnancy was associated with a 0.074 increase in the child’s index score of sleep problems. Increases in this score indicate more difficulty falling and staying asleep from 1 month to 12 years.

In a separately tested model, postnatal cigarette smoke exposure was no longer significant when entered into a regression model after prenatal nicotine exposure and covariates; that is, it did not explain sleep problems above and beyond prenatal nicotine exposure and the other covariates.
The main finding from this study was that in a large sample of children with prenatal exposure to cocaine, opiates, marijuana, alcohol, and/or nicotine there is a unique effect on sleep problems between 1 month and 12 years for nicotine in both unadjusted and adjusted analyses. This was a dose-response effect for prenatal nicotine exposure with adjustment for covariates. Higher levels of prenatal nicotine exposure predicted more sleep problems, specifically difficulty falling and staying asleep from 1 month to 12 years. This effect was observed controlling for postnatal maternal/caregiver use of cigarettes.

The finding that prenatal nicotine exposure predicted sleep problems in children is consistent with studies of smokers showing sleep disruption attributable to nicotine\(^27\)\(^28\) and supports a recent study that found that prenatal maternal smoking resulted in less sleep and more fragmented sleep among newborns.\(^12\) Preclinical studies of prenatal nicotine exposure have shown abnormal cardiorespiratory response during sleep,\(^29\) altered sleep-state maturation,\(^30\) and decreased rapid eye movement (REM) sleep.\(^31\)

A recent study documented significantly less sleep in infants after drinking breast milk that contained nicotine than after drinking nicotine-free breast milk (53 vs 85 minutes).\(^32\)

There are several ways through which nicotine can affect sleep. Nicotine has been shown to excite pedunculopontine nucleus cells, which are involved in sleep-wake mechanisms\(^33\); to suppress pontogeniculopontine spike activity, which influences the initiation and maintenance of REM sleep;\(^34\) and to inhibit sleep-promoting neurons in the ventrolateral preoptic area.\(^35\)

When investigating prenatal exposure to cocaine, opiates, marijuana, alcohol, and nicotine, we found dose-response effects of prenatal nicotine exposure only on sleep problems in a large sample of children aged up to 12 years. Caution should be taken when concluding that prenatal nicotine exposure is more damaging to sleep than other prenatal drug exposure, given the current study’s specific limitations (namely the subjectivity of the sleep problems index) and the study’s operationalization of “sleep problems” (ie, difficulty falling and staying asleep). Whether or not there are associations between prenatal drug exposure and other types of sleep problems (eg, sleep-disordered breathing) is unknown and was not investigated in this study. Our study is also limited by the use of maternal self-report for our measures both of sleep problems in the children and of caregiver postnatal substance use. Validated parent-reported sleep problems questionnaires would have been preferable to our index composed of items from the Child Behavior Checklist, the Child Health and Illness Profile, Pediatric Symptom Checklist, and general health questionnaire. To our knowledge, this type of validated instrument does not yet exist to measure sleep during the first 12 years of life or pediatric difficulties falling and staying asleep specifically, and therefore this limitation points to an important need in the field. Furthermore, it would be useful to conduct formal sleep studies on these children and validate environmental tobacco exposure and postnatal substance use with toxicological assays.

This is the first longitudinal study of the effects of prenatal drug exposure on sleep problems over time with adjustment for multiple covariates (SES, marital status, ethnicity, sex, and gestational age).
physical or sexual abuse, prenatal care, clinic site, and postnatal cigarette smoke exposure) and with adequate power to detect a dose-response association. Findings suggest a link between prenatal nicotine exposure and persisting sleep problems in children for the first 12 years of life. Understanding the persisting nature of sleep problems in children with prenatal adversity, including substance exposure, could be a critical component to improving developmental outcomes in this population. Sleep problems may mediate some of the other developmental effects of prenatal exposure to nicotine. Assessing the risk for sleep problems in children with prenatal exposure to nicotine and other drugs is the first step toward creating efficient, proactive services that will foster optimal sleep and corresponding daytime functioning.

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