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Effects of prenatal cigarette smoke exposure on neurobehavioral outcomes in 10-year-old children of adolescent mothers

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ABSTRACT

In this prospective study, adolescent mothers (mean age = 16; range = 12–18; 70% African-American) were interviewed about their tobacco use during pregnancy. When their children were ten, mothers reported on their child's behavior and the children completed a neuropsychological battery. We examined the association between prenatal cigarette smoke exposure (PCSE) and offspring neurobehavioral outcomes on data from the 10-year phase ($n = 330$). Multivariate regression analyses were conducted to test if PCSE predicted neurobehavioral outcomes, adjusting for demographic characteristics, maternal psychological characteristics, prenatal exposure to other substances, and exposure to environmental tobacco smoke. Independent effects of PCSE were found. Exposed offspring had more delinquent, aggressive, and externalizing behaviors (CBCL). They were more active (Routh, EAS, and SNAP) and impulsive (SNAP) and had more problems with peers (SNAP). On the Stroop test, deficits were observed on the more complex interference task that requires both selective attention and response inhibition. The significant effects of PCSE on neurobehavioral outcomes were found for exposure to as few as 10 cigarettes per day. Most effects were found from first trimester PCSE exposure. These results are consistent with results from an earlier assessment when the children were age 6, demonstrating that the effects of prenatal tobacco exposure can be identified early and are consistent through middle childhood.

1. Introduction

The rate of teenage pregnancy in the U.S. remains significantly higher than in other developed countries (Darroch et al., 2001), and it is estimated that one-third of all American girls will get pregnant by age 20. Smoking is common among pregnant adolescents, with an estimated 20–50% of pregnant adolescents smoking. This is compared to 10–15% of all pregnant women (Allen et al., 2008), and 15.6% of non-pregnant adolescents (Johnston et al., 2005). Using the most conservative estimate, if 20% of the 435,427 girls aged 15–19 who gave birth in 2006 (Hamilton et al., 2007) smoked while they were pregnant, at least 87,085 American infants were exposed to gestational tobacco from these teenage pregnancies alone. The health of these children is compromised by prenatal cigarette smoke exposure (PCSE), which has been associated with negative outcomes at birth, during childhood, adolescence and adulthood (Batstra et al., 2003; Brennan et al., 1999; Burke et al., 2007; Cornelius et al., 1995, 1999, 2002, 2003, 2005, 2007; Fergusson et al., 1993, 1998; Huizink & Mulder, 2006; Kandel et al., 1994; Mick et al., 2002; Milberger et al., 1996; Olds, 1997; Stroud et al., 2009b; Weissman et al., 1999).

Recent reviews of the literature provide significant support for concern about the neurobehavioral (NB) effects of PCSE on exposed offspring. Many of the more recent studies use prospective designs, biological measures of tobacco exposure, and multivariate statistical analyses designed to control for possible confounds (Button et al., 2007; Cornelius & Day, 2009; Picket et al., 2009; Shea & Steiner, 2008). The effects of PCSE range from irritability and poor self-regulation during infancy (Mansi et al., 2007; Shea & Steiner, 2008; Stroud et al., 2009a,b) to behavior problems during childhood (Carter Test, 2008; Cornelius et al., 2007; Gatzke-Kopp & Beauchaine, 2007; Orlebeke et al., 1999; Robinson et al., 2008; Weitzman et al., 1992). For example, preschoolers with PCSE in the Raine Study (Robinson et al., 2008) were significantly more likely to have externalizing and internalizing problems than were preschoolers without PCSE, even after controlling for maternal age and SES, perinatal health status, breastfeeding, and symptoms of postnatal depression. Additionally, longitudinal studies have demonstrated negative effects of PCSE on adolescent (Cornelius et al., 2005; Myers & Weissman, 1980; Olds, 1997) and adult behavior (Brennan et al., 1999; Burke et al., 2007).

There are many factors that lead to neurobehavioral deficits and women who smoke during pregnancy are more likely to exhibit these

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risk factors, including other maternal risk behaviors (Adams et al., 2008; Burns et al., 2008), poverty (Martin et al., 2008), and parental psychopathology (Huijbregts et al., 2008). In addition, women who smoke during pregnancy are more likely to expose their children to environmental tobacco smoke (ETS) in the postpartum (Cornelius et al., 2003; DiFranza et al., 2004). ETS has also been linked to behavior problems (Eskenazi & Trupin, 1995; Fergusson et al., 1993; Williams et al., 1998; Yolton et al., 2008). Therefore, it is important to include measures of other prenatal substance exposures and environmental factors when testing for teratological effects on behavior in longitudinal studies (Eskenazi & Castorina, 1999).

Further, the children of adolescents are at greater risk than children of older mothers for infant morbidity and mortality, cognitive impairment, social and behavioral deficits, child abuse and neglect, and early and pervasive school failure (Babsin & Clark, 1983; Furstenberg et al., 1990; Moore & Snyder, 1991; Sommer et al., 2000; Zuckerman et al., 1984). Differences between children of adolescent and adult mothers decrease, but remain significant, when factors such as maternal economic, marital, and educational status are controlled in analyses (Children's Defense Fund, 1985). Moreover, the incidence of negative sequelae among children of adolescent mothers only increases as the child gets older (Furstenberg et al., 1990; Moore & Snyder, 1991), so it is important to identify areas where early prevention might be most effective for these children.

To our knowledge, this is the first study to investigate the effect of PCSE on neurobehavioral (NB) outcomes during middle childhood in the offspring of adolescent mothers. In this prospective study, we collected trimester-specific data on maternal substance use including tobacco, alcohol, marijuana and other illicit drugs during pregnancy and in the postpartum. We assessed NB outcomes in the offspring at age 10. We hypothesized that PCSE would predict an increased rate of child NB problems in the offspring of adolescent mothers, and that this association would remain significant after controlling for covariates of maternal smoking such as other substance use and environmental factors.

2. Materials and methods

2.1. Sample selection and study design

The data on adolescent mothers and their offspring come from the Teen Mother Study that is part of the Maternal Health Practices and Child Development (MHPCD) project, a consortium of studies on the long-term effects of prenatal substance use. The pregnant adolescents were recruited from the Magee-Womens Hospital prenatal clinic from 1990–1994. The adolescents were seen during a prenatal visit and at delivery with their newborn infants. Follow-up visits were at 6 and 10 years in our laboratory with mothers and children. The 6- and 10-year follow-up visits took place between 1996–2000 and 2000–2004, respectively. The Institutional Review Boards of the Magee-Womens Hospital and the University of Pittsburgh approved each phase of this study. Participants were informed about confidentiality and assured that their information was protected by a Certificate of Confidentiality issued by the National Institute on Drug Abuse (NIDA).

The participants were recruited in the second trimester of their pregnancies, when they came into the clinic for their fourth or fifth prenatal visit. In a private room at the clinic, the pregnant adolescents were interviewed about their current and previous (during the first trimester and one year prior to becoming pregnant) tobacco, alcohol, marijuana, and other drug use. The adolescents were seen again 24–36 hours after delivery, when they were interviewed about their substance use during the second and third trimesters of the pregnancy. At the 6-year and 10-year follow-up visits at our offices, the mothers provided information about their recent substance use (current and past year) as well as their demographic and psychological status. Medical histories were taken at this time for both mothers and children. NB measures of the children were included in the protocol for the 10-year visit. Reports on maternal substance use, growth of the offspring, and 6-year outcomes have been provided in previous reports (Cornelius et al., 1995, 1999, 2002). The present report focuses on the effects of PCSE on NB outcomes of the 336 10-year-old offspring.

2.2. Sample description

All of the pregnant adolescents attending the prenatal clinic, who were under the age of 19, were eligible for the present study. This included 448 pregnant girls aged 12–18 years. Of the 448 girls who were originally approached to participate in the study, 3 refused, for an initial refusal rate of 0.7%. Of the remaining 445 pregnant teenagers, 15 moved out of the area prior to delivery, and 1 refused the delivery interview. Additional losses included six twin births, five spontaneous abortions, two still-born infants, and three live-born premature infants who died. Thus, 413 live-born singletons and their teenage mothers were assessed at delivery.

A total of 330 women and their offspring were assessed at the 10-year follow-up phase: 24 mothers refused to participate, 39 were lost to follow-up, 10 had moved out of the state, 2 children were in foster care, 7 children had died, and 1 child was adopted. Prenatal substance exposure and SES did not differ significantly between the mothers and children seen at the 10-year follow-up and those who were not seen at 10 years.

The women, on average, were 16.3 years old (range = 12–18) at study recruitment: 75% were 16 years or older, and 25% were less than 15 years of age. Sixty-nine percent were African-American, 31% were Caucasian, and 99% of them were unmarried at delivery (Cornelius et al., 1995). At the 10-year follow-up, the mothers' average monthly income was $1,788 (range = $0–$9,990) and their mean education was 12.6 years (range = 7–18). Most of the mothers (88%) had completed high school or received a General Equivalency Diploma (GED). Three percent had completed college. A majority of the women (76%) were not currently married. Most of the children (87%) were living with their biological mothers at the age 10-year follow-up; the remaining 13% of the children were with a custodian. If a child was not living with his or her mother, the current custodian was interviewed. Of the mothers who were living with their children, 13.4% were living with the child's father, 29.1% lived with a husband or boyfriend who was not the child's father, and 48.8% were living alone with their children.

2.3. Measures of substance use

The substance use measures used in this study were developed and extensively tested for studies of alcohol and marijuana use during pregnancy in adult women. The questions were developed to reflect accurately both the pattern and level of use (Day & Robles, 1989). At all phases of testing, the participants were interviewed in a private setting by interviewers who were comfortable discussing alcohol and drug use, trained to use the instrument reliably, accurately identify the drugs used, and assess the amount of use. For substance use during pregnancy, calendar landmarks were used to indicate time periods that corresponded with conception and recognition of pregnancy. Assessment was done for each trimester of pregnancy. To ascertain the level of cigarette smoking during pregnancy, we asked: “Do you smoke cigarettes? How old were you when you started smoking? What brand do you usually smoke? How many cigarettes do you smoke on a typical day? Has your smoking changed since you've been pregnant? How and when did your smoking change? How many cigarettes did you smoke on a typical day before you changed?” Average daily cigarettes was quantified using the responses of those who did not change smoking and recalculated for those who reported changes in smoking for the first trimester. At