Neurotoxicology and Teratology 33 (2011) 88–99

Contents lists available at ScienceDirect

Neurotoxicology and Teratology

journal homepage: www.elsevier.com/locate/neutera

Early adolescent cocaine use as determined by hair analysis in a prenatal cocaine exposure cohort

Tamara Duckworth Warner [a,1], Marylou Behnke [a,*], Fonda Davis Eyler [a], Nancy J. Szabo [b]

[a] University of Florida, Department of Pediatrics, P.O. Box 100296, Gainesville, FL 32610-0296, United States
[b] University of Florida, Department of Physiological Sciences, College of Veterinary Medicine, P.O. Box 110885, Gainesville, FL 32611-0885, United States

ARTICLE INFO

Article history:
Received 1 October 2009
Received in revised form 3 July 2010
Accepted 6 July 2010
Available online 18 July 2010

Keywords:
Prenatal cocaine exposure
Early adolescents
Hair
Drug testing
Substance abuse

ABSTRACT

Background: Preclinical and other research suggest that youth with prenatal cocaine exposure (PCE) may be at high risk for cocaine use due to both altered brain development and exposure to unhealthy environments.
Methods: Participants are early adolescents who were prospectively enrolled in a longitudinal study of PCE prior to or at birth. Hair samples were collected from the youth at ages 10½ and 12½ ($N = 263$). Samples were analyzed for cocaine and its metabolites using ELISA screening with gas chromatography/mass spectroscopy (GC/MS) confirmation of positive samples. Statistical analyses included comparisons between the hair-positive and hair-negative groups on risk and protective factors chosen *a priori* as well as hierarchical logistical regression analyses to predict membership in the hair-positive group.
Results: Hair samples were positive for cocaine use for 14% ($n = 36$) of the tested cohort. Exactly half of the hair-positive preteens had a history of PCE. Group comparisons revealed that hair-negative youth had significantly higher IQ scores at age 10½; the hair-positive youth had greater availability of cigarettes, alcohol, and other drugs in the home; caregivers with more alcohol problems and depressive symptoms; less nurturing home environments; and less positive attachment to their primary caregivers and peers. The caregivers of the hair-positive preteens reported that the youth displayed more externalizing and social problems, and the hair-positive youth endorsed more experimentation with cigarettes, alcohol, and/or other drugs. Mental health problems, peer drug use, exposure to violence, and neighborhood characteristics did not differ between the groups. Regression analyses showed that the availability of drugs in the home had the greatest predictive value for hair-positive group membership while higher IQ, more nurturing home environments, and positive attachment to caregivers or peers exerted some protective effect.
Conclusion: The results do not support a direct relationship between PCE and early adolescent experimentation with cocaine. Proximal risk and protective factors—those associated with the home environment and preteens' caregivers—were more closely related to early cocaine use than more distal factors such as neighborhood characteristics. Consistent with theories of adolescent problem behavior, the data demonstrate the complexity of predicting pre-adolescent drug use and identify a number of individual and contextual factors that could serve as important foci for intervention.

1. Introduction

1.1. Adolescent substance use in the United States

Adolescence, considered to range broadly from 11 to 18 years, is a time of increased risk-taking behavior among humans, as well as other species [88]. Experimentation with illicit drugs is among the many unhealthy risky behaviors in which teenagers engage and represents a significant public health problem. The drugs most commonly tried by teens are tobacco, alcohol and marijuana [47,73]. The most recent data from the NIDA-funded Monitoring the Future study indicated that almost half of all high school seniors (47%) and more than a quarter of 8th graders (28%) have used some illicit drug during their lifetime [48]. The Pride Survey extended these findings downward and showed that 7% of 6th graders and 10% of 7th graders reported use of illicit drugs in the past year [73].

Although cocaine and crack use among secondary school students has generally been declining since peak rates in 1999, the lifetime prevalence rates for cocaine use among each of the three survey groups in the Monitoring the Future study – 8th, 10th, and 12th graders – have increased significantly at least once between 2004 and 2008. The most recent lifetime prevalence estimates are 3.0% for 8th graders, 4.5% for 10th graders and 7.2% for 12th graders. The annual prevalence rates for

* Corresponding author. Tel.: +1 352 273 8985; fax: +1 352 273 9054.
E-mail addresses: warnert@ecu.edu (T.D. Warner), behnkem@peds.ufl.edu (M. Behnke), eylerfd@peds.ufl.edu (F.D. Eyler), nszabo@ufl.edu (N.J. Szabo).
[1] Current address: East Carolina University, Department of Psychology, 104 Rawl Building, Greenville, NC 27858-4353, United States. Tel.: +1 252 328 6282; fax: +1 252 328 6283.

0892-0362/$ – see front matter © 2010 Elsevier Inc. All rights reserved.
doi:10.1016/j.ntt.2010.07.003

crack use specifically in the Monitoring the Future survey are the same for 8th and 10th graders at 2.0%, which is only slightly lower than for 12th graders at 2.8% [48]. Even more worrisome in the Pride Survey is the reported annual prevalence rate of 1.2% for both 6th and 7th graders [73].

Earlier experimentation with cocaine is linked to a greater likelihood of developing cocaine dependence. A study using data from the National Comorbidity Survey demonstrated that for adolescents who used cocaine at least once, the estimated cumulative probability of meeting diagnostic criteria for cocaine dependence increased seven-fold from ages 15 to 19. Additionally, the risk of developing dependence extends a decade or more after initial use, a much larger window of vulnerability compared to marijuana [93]. An increased risk of drug dependence with very early use was also demonstrated by Anthony et al. who found that a 68% risk of developing drug problems when use of illicit drugs began at less than age 13 compared to 43% for those who began at age 16 [3].

1.2. Determination of adolescent substance use

Serious substance use problems in adolescents may be underestimated because an important limitation of most studies is reliance on self-report. In a sample of pregnant adolescents, Bessa et al. [11] compared responses to drug use questions in a structured interview with analysis of hair samples and found that hair analyses detected the use of cocaine and/or marijuana in 6% of participants, none of whom had self-reported use. Studies of known adult cocaine users also have demonstrated that hair samples are far more sensitive than self-report or urine tests for detecting drug use, especially cocaine [31,67].

Hair specimens have several advantages over urine samples for detecting drug use by toxicological analyses [9,28]. The window of drug detection when using hair can be months to years depending upon the length of the hair specimens compared to 2–3 days for urine, an important advantage when attempting to identify occasional users. Hair analysis, unlike urinalysis, is not susceptible to evasive measures on the part of the participant. Hair analysis is particularly suited for detection of cocaine use given that cocaine has the highest incorporation rate into hair compared to other common drugs of abuse due to its high lipophilicity and basicity [72].

Concerns about contamination of hair that can result from passive exposure to drugs in the environment have been addressed by sample preparation techniques and analytic methods developed and validated by more than 15 years of research. One of the most important sample preparation issues is washing the hair to remove external cocaine contaminates while leaving the internal hair structures intact. While there is no general consensus on the optimal hair washing procedure, one validated method involves an isopropanol wash followed by multiple extended phosphate buffer washes [16,83,84]. This procedure has been tested using various colors of hair (blonde, auburn, brown, and black) and both natural and chemically treated hair. These studies demonstrated that the porosity of hair, not its color, affects the rate of penetration of hair by cocaine in solution (i.e., chemically treated hair absorbs cocaine more easily than natural hair) [83]. Cocaine is less affected by cosmetic treatments than other drugs [72]. Hair that has been subjected to harsh cosmetic treatments, such as oxidative dyeing and bleaching, when appropriately washed, yields somewhat lower though still detectable levels of cocaine [20,50,98].

1.3. Adolescent vulnerability to cocaine

Preclinical studies using periadolescent rodents suggest that, compared to adults, adolescents may have an increased biological vulnerability to stimulants, including cocaine (for a review see Laviola et al. 1999[53]). This increased vulnerability may be due, in part, to greater reinforcement of novelty-seeking behavior through dopaminergic reward systems in the brain, particularly for those who are high in activity level, sensation-seeking, and/or impulsivity [90]. In addition, female adolescent rats may be at particularly high risk for cocaine dependence given that adolescents showed heightened sensitivity to cocaine compared to adults and females respond to lower doses of cocaine compared to males [99].

Youth with a history of prenatal cocaine exposure (PCE) may be at an increased risk for using cocaine due to alterations in fetal brain development as well as exposure to high-risk environments. Animal models of PCE have demonstrated both structural and functional changes in dopamine-rich brain circuits [36,37,39,56,91]. These are important findings as the dopaminergic system is linked to the rewarding properties of drugs of abuse. In well-controlled studies, significantly smaller birth head circumferences among children with PCE have been reported [5,8,22,30,58,77,86,87,100]. Head circumference, at birth and in young children, is a reliable indicator of brain volume and growth [7,57].

A long history of research has documented that children of parents with a substance use disorder are at higher risk for substance use problems due to both genetic and environmental influences. For example, in a study by Noble et al., a significantly higher prevalence of the A1 and B1 alleles of the D2 dopamine receptor gene was found in male cocaine addicts when compared with non-cocaine users, suggesting a genetic susceptibility to cocaine dependence and raising the possibility of genetic transmission to offspring [69]. However, the intergenerational transmission of the risk for substance abuse is thought to be only partly genetic. Parental modeling of drug use as well as a variety of interrelated psychosocial factors including maternal/caregiver psychopathology, parenting problems, family dysfunction, violent neighborhoods, and poverty are important contributors to the development of offspring substance abuse as well [25,59,63,64]. The role of fetal exposure to drugs of abuse as an additional risk factor for later substance use among children of substance abusing parents remains unclear. The reader is referred to comprehensive reviews available on this topic [35,46].

1.4. Models for understanding adolescent problem behavior including drug use

A number of theories of child and adolescent development posit that behaviors are influenced by the interaction between an individual's unique characteristics and abilities and multiple levels of his/her environment [15,54,60,70]. A common element of models of adolescent development generally, and of developmental psychopathology in particular, is a focus on social relationships in multiple contexts and settings, including families, friends, and peers in homes, schools and neighborhoods [32,70]. These models derive from a number of developmental theories (e.g., attachment, social learning and ecological–transactional theories) [6,12,19,41,79,89] which highlight the influence of relationships on social behavior and development.

Several theoretical models specific to adolescent problem behaviors propose that risk and protective factors exist at multiple levels — the individual level (including personal attributes), the contextual level (home, school, neighborhood), and the interpersonal level (parents, family, peers, other adults) [18,19,23,45,55,62,66,75,89]. For example, Dishion and colleagues have suggested that poor self esteem, depression, and skill deficits may confer a vulnerability to substance use [27]. Examining factors affecting substance use in adolescent males, Dishion et al. found interconnections among individual youth, family, and peer characteristics which led them to propose a higher order construct they call a “childhood risk structure” [25]. Similarly, Jessor's model of adolescent risk behavior includes five interrelated domains of risk and protective factors: biology/genetics, personality, behavior, the perceived environment, and the social environment [45].

Extensive empirical work based on these models has identified a number of specific risk and protective factors related to parental functioning, family functioning, peer relations, and neighborhood characteristics that affect the likelihood and extent to which adolescents will engage in alcohol and drug use as well as other risky behaviors. For example, parental affective disorders and drug use have been related to