

Effects of prenatal marijuana exposure on child behavior problems at age 10

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Abstract

This is a prospective study of the effects of prenatal marijuana exposure on child behavior problems at age 10. The sample consisted of low-income women attending a prenatal clinic. Half of the women were African-American and half were Caucasian. The majority of the women decreased their use of marijuana during pregnancy. The assessments of child behavior problems included the Child Behavior Checklist (CBCL), Teacher's Report Form (TRF), and the Swanson, Noland, and Pelham (SNAP) checklist. Multiple and logistic regressions were employed to analyze the relations between marijuana use and behavior problems of the children, while controlling for the effects of other extraneous variables. Prenatal marijuana use was significantly related to increased hyperactivity, impulsivity, and inattention symptoms as measured by the SNAP, increased delinquency as measured by the CBCL, and increased delinquency and externalizing problems as measured by the TRF. The pathway between prenatal marijuana exposure and delinquency was mediated by the effects of marijuana exposure on inattention symptoms. These findings indicate that prenatal marijuana exposure has an effect on child behavior problems at age 10. © 2000 Elsevier Science, Inc. All rights reserved.

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1. Introduction

Marijuana is the illicit drug most commonly used by pregnant women. In a recent national survey of the prevalence and patterns of substance use among pregnant women, 2.8% reported marijuana use during their first trimester of pregnancy compared with 0.9% who reported cocaine/crack use during the first trimester [30]. Prenatal marijuana use has been found to affect the child's central nervous system and cognitive development (e. g., [10,13,19,20,31,37]). However, little is known about the long-term effects of prenatal marijuana exposure on behavior problems of the offspring. Only one other longitudinal study has addressed this issue.

The Ottawa Prenatal Prospective Study is a longitudinal study of the effects of prenatal marijuana exposure in a sample of white, mostly middle class women. At the six-year follow-up, they found a statistically significant association between prenatal marijuana exposure and increased errors of omission, a measure of attention, on a vigilance task [20]. The exposed children were also rated by their mothers as more impulsive and hyperactive on the Conners' Parent

Rating Scale [23] than were the nonexposed children. Current substance use in the household was not controlled in these analyses. At a follow-up when the children were 6 to 9 years old, O'Connell and Fried [31] found that children exposed to cannabis prenatally were rated by their parents as having more conduct problems, as measured by the Conners' Rating Scale, than the nonexposed group. However, the difference between the two groups was not statistically significant after controlling for the confounding variables.

In the Maternal Health Practices and Child Development Study (MHPCD), prenatal marijuana exposure was not associated with the mother's assessments of the children's behavior at three years [12]. At the 6-year follow-up of the same cohort, exposure to marijuana during the second and third trimesters of pregnancy was found to be significantly related to the teacher's reports of delinquent behavior problems [8].

There are several difficulties in estimating the effects of prenatal substance exposure on the offspring's behavior, which may account for the paucity of research in this area [11,38]. First, it is difficult to isolate the effects of marijuana exposure from its correlates and from environmental risk factors. Variables such as socioeconomic status, family size, neighborhood characteristics, presence or absence of a male in the household, and ethnic background have a signif-

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icant influence on child development [16,18,34,39,45], as do maternal depression [4,5], family interaction styles [41], social support [9,25], and stressful life events [6,34]. Each of these factors is also associated with marijuana use. Second, it is difficult to obtain a reliable and valid measure of maternal illicit drug use. To the extent that the level of exposure is misreported, erroneous interpretation of the results will occur. Third, it is often difficult to obtain an adequate and objective assessment of child behavior. Maternal reports can be biased, and this bias may be directly related to current substance use. Fourth, longitudinal studies are susceptible to the loss of subjects over time, resulting in misrepresentation of the cohort and lack of power to find a significant difference between the exposed and the nonexposed groups.

The purpose of the present study is to investigate the relationship between prenatal marijuana exposure and child behavior at age 10. There are several advantages to the current study that overcome the methodological difficulties listed above. In the MHPCD Project, information about the child's environment, sociodemographic characteristics, maternal psychosocial status, and maternal current illicit drug, tobacco, and alcohol use was collected, permitting the examination of effects of prenatal marijuana exposure on offspring behavior while statistically controlling for these extraneous variables. Child behavior problems were assessed in multiple ways and the assessments included behavior ratings by two observers, teachers and caregivers. The MHPCD Project developed a detailed assessment of substance use that was administered at repeated and relatively short intervals, minimizing recall error. In addition, the MHPCD has a large sample size and high retention rates, insuring nonbiased attrition and facilitating statistically powerful tests of the effects of marijuana.

2. Methods

2.1. Sample selection and interview schedule

The study sample consisted of women and their offspring who are participants in the MHPCD Project. Women attending the prenatal clinic at the Magee–Womens Hospital were interviewed when they came in for their fourth-month examination. A total of 1360 women who were 18 years of age or older was interviewed. Two samples were selected from the initial interview to study the effects of prenatal marijuana and alcohol exposure on the offspring. All women who used two or more joints of marijuana per month during the first trimester and a random sample of women who used less than this amount were selected for the marijuana cohort. All women who drank three or more times a week and a random sample of women who drank less than this amount were selected into the alcohol cohort. Women could be selected for either or both cohorts. For this report, the two cohorts were combined. The study was approved by the Institutional Review Boards of the Magee–Womens Hospital and the University of Pittsburgh.

Information about marijuana and other substance use during the first, second, and third trimesters of pregnancy was collected at the initial interview at 4 months, at the seventh prenatal month, and at 24 to 48 hours postdelivery, respectively. The women were interviewed again at 8 and 18 months, 3, 6, and 10 years postpartum. The 14-year follow-up is currently being conducted. The interviews included questions about current maternal substance use, social and psychological status, and the environment of the study child. At each phase, the growth, cognitive development, temperament, and behavioral characteristics of the offspring were assessed using age-appropriate measurements. The 10-year follow-up was conducted from 1994 through 1997.

2.2. Description of the study cohort

At birth, 763 live singleton infants and their mothers participated in the study. From birth to the 10-year phase, 5 infants died, 46 families moved out of state, 3 children were placed for adoption, 8 mothers lost custody and the children could not be traced, 40 mothers refused to participate, and 25 were lost to follow-up. The 636 subjects interviewed at the 10-year follow-up represented 91% of the eligible subjects and 83% of the birth cohort. One mother did not complete the behavior questionnaires and 60 teachers did not respond. Thus, the final cohort for this analysis included 635 mother's reports and 575 teacher's reports. There were no significant differences in prenatal substance use between women who were eligible but did not participate in the study at 10 years ($n = 65$) and those who did participate ($n = 635$). Among those included in this analysis, there were no significant differences in prenatal or current substance use, current environment, or maternal behavior ratings between the subjects with a completed teacher's report form ($n = 575$) and those who did not have a teacher's report form ($n = 60$).

In addition, information about second trimester prenatal substance use was missing for 60 of the women interviewed at the 10-year follow-up phase because they did not return to the clinic for the second trimester prenatal visits. There were no significant differences in first and third trimester substance use or sociodemographic characteristics between the women who missed the second trimester interview and those who did not miss the second trimester interview.

The subjects in the study were of low socioeconomic status. At the first interview, the median family income was \$350 per month, 32% of the women were married, and 27% worked and/or studied outside of the home. Forty-seven percent of women were Caucasian and 53% were African-American. The women were, on average, 23 years old (range = 18–42) and had 11.8 years of education (range = 8–18).

At 10 years postpartum, the median family income was \$1245 per month. Sixty-two percent of the women worked and/or studied outside of the home and, on average, they had 12.2 years of education. Forty-one percent of women were married, but 54% reported having an adult male living in the household.

The children were, on average, 10.5 years old ($SD = 0.5$, range = 10–13) at the assessment. Fifty percent of the children were males. Forty-four percent of the children were in the fifth grade (range = 2–8). Twenty-three percent of the children had repeated one or more grades. Mothers reported that 21 children (3.3%) were taking medication for attention deficit hyperactivity disorder. Eight percent of the children were not in the custody of their biological mother. In these cases, the current caretaker was interviewed.

2.3. Measures

2.3.1. Marijuana use

Marijuana use was assessed using the methods developed by the MHPCD Project. The women were asked about their maximum, minimum, and usual amount and frequency of marijuana, hashish, and sinsemilla use. Hashish and sinsemilla were translated into joints of marijuana based on the relative amounts of Δ -9-tetrahydrocannabinol in each substance [22, 27]. A bowl or a joint of hashish was counted as three joints of marijuana, and sinsemilla was transformed to two joints of marijuana. The subjects were also asked how often they used more or less than the usual amount, and this information was combined with their usual pattern of use. The details of this methodology are described elsewhere [14]. Marijuana use was assessed for each month of the first trimester, and across the entire trimester for the second and third trimesters of pregnancy. At the 10-year follow-up, the women reported their marijuana use over the past year.

2.3.2. Other substance use

Alcohol use was measured using the same methodology as marijuana use. The women were asked about the minimum, maximum, and usual quantity and frequency of beer, wine, liquor, beer cooler, and wine cooler use. Alcohol use was calculated as the average number of drinks per day. Tobacco use was expressed as the average number of cigarettes smoked per day. Although the subjects were asked about the frequency and quantity of their cocaine use, for these analyses, cocaine was defined as a dichotomous variable indicating use/no use.

2.3.3. Child behavior problems

Three instruments were used to assess the child's behavior problems, the Swanson, Noland, and Pelham (SNAP) [32] assessment, the Child Behavior Checklist (CBCL) [1], and the Teacher's Report Form (TRF) [2].

The SNAP questionnaire is completed by the mothers. The SNAP consists of 25 questions that elicit the symptoms for the DSM-III definition of attention deficit disorder with hyperactivity. The SNAP items are factored into four subscales representing hyperactivity, inattention, impulsivity, and peer problems [32].

The CBCL is completed by the mother or current caregiver. It consists of 118 questions representing behavior and emotional problems that are of concern to parents and mental health professionals. The scale is factored into nine

traits: withdrawn, somatic complaints, anxious/depressed, social problems, sex problems, thought problems, attention problems, delinquent behavior, and aggressive behavior. The first three traits are grouped together to represent total internalizing problems, and the last two traits are grouped to represent total externalizing problems. A total behavioral problems score is also calculated. The scores are standardized based on the child's age and gender. The test-retest reliability of the CBCL is 0.89, and the mean inter-parent agreement is 0.75 for boys and 0.65 for girls [1].

The TRF was completed by the child's teacher. The TRF items and constructs are similar to those of the CBCL, although the TRF does not have the sex problems scale. The test-retest reliability and inter-teacher agreement are 0.92 and 0.6, respectively [2].

A score of 67 is defined as the borderline clinical cutoff score for the CBCL and TRF individual subscales. These scores were chosen because they best discriminated between deviant and nondeviant children [1].

2.3.4. Maternal socioeconomic status

Socioeconomic status was defined by: number of years of education, working/studying outside of the home (yes/no), monthly family income, race/ethnicity (Caucasian/African-American), and presence of husband or boyfriend in the household (yes/no).

2.3.5. Maternal psychosocial characteristics

Maternal depression, hostility, and the number of reported life events were used to assess psychological status. Maternal depression was assessed using the Center for Epidemiological Studies-Depression Scale (CES-D) [33], hostility was measured by the Spielberger State-Trait Anxiety Inventory [40], and life events were measured by questions adapted from Dohrenwend et al. [15]. Two variables were used to describe social support: coping ability and support from relatives. Coping ability was assessed using the Social Network Form [43] and support from relatives was based on questions adapted from the Human Population Laboratory studies [7]. A factor analysis was applied to agglomerate the questions into smaller sets of variables. The mother's report about her ability to cope with household tasks, child care, emotional well-being, and bills were factored together representing maternal coping ability. The scale ranged from 1 (out of control most of the time) to 5 (in control most of the time). Support from relatives included maternal reports on having relatives to turn to in times of need, satisfaction with the help she received from relatives, and the amount of support she received as a mother. The scale ranged from 0 (none) to 4 (all the time).

2.3.6. Child's environment

Several variables were used to describe the child's environment. The Home Observation for Measurement of the Environment-Short Form (HOME-SF) [3], completed by the mother, was used to assess the quality of the cognitive stimulation and emotional support provided by the child's

family. The level of overt aggression among family members was measured by the conflict subscale of the Family Environment Scale [29]. Number of siblings in the household and a dichotomized variable indicating whether the child was in maternal custody (yes/no) were also used as measures of the child's environment.

2.4. Data analysis

Marijuana use was expressed as the average number of joints per day (ADJ). Prenatal marijuana use was treated both continuously and categorically. For the continuous variable, since the frequency distribution of marijuana use was positively skewed, a log linear transformation was used to reduce skewness. For the categorical analyses, two different cutpoints were used. First trimester marijuana users were divided into three groups: abstainers, light to moderate users ($0 < \text{ADJ} \leq 0.89$), and heavy users ($\text{ADJ} > 0.89$). Second and third trimester marijuana use were categorized into: no use, light use ($0 < \text{ADJ} \leq 0.4$), and moderate to heavy use ($\text{ADJ} > 0.4$) because fewer women used marijuana heavily during the later part of their pregnancy. The cutpoint of $\text{ADJ} > 0.89$ is equivalent to one or more joints/day. This is calculated using the following formula: $(7 \text{ joints/week} \times 4 \text{ weeks/month})/31 \text{ days/month}$. An ADJ of 0.4 is about three joints/week.

The relations between prenatal marijuana use and behavior problems were first explored bivariate using scatter plots, zero-order correlations, and comparison of means and frequencies of behavior problems for different categories of marijuana use.

Stepwise multiple regression was used to analyze the effects of prenatal marijuana exposure on the SNAP and the total, internalizing, and externalizing T-scores of the CBCL and TRF, while controlling for other predictors. Variables reported in the literature to be related either to problem behavior or marijuana use were considered for inclusion in the model as covariates (Table 1). For all the analyses, predictors that were significant at an alpha level of 0.05 were retained for the final models. Where marijuana was found to be a significant predictor, the regression coefficient (coef.) and its significance level (p) were reported. Type I error was not adjusted for the number of behavior outcomes analyzed because these variables were not completely independent of each other and dividing alpha by the number of outcome variables would be too conservative. Hence, the actual p value may be slightly larger than reported.

The regression analyses were screened for outliers and influential points to insure that the results were not based on a few cases. The tolerances of the variables in the final models were examined to ascertain that the coefficients were not unstable due to multicollinearity.

Multiple regression analysis was not applied to the subscales of the TRF and CBCL because of their highly skewed distributions. Instead, stepwise logistic regression was used to compare the children who were rated above and below

the borderline clinical cutoff T-score on the CBCL and TRF subscales. To avoid lack of convergence in the logistic regression analyses, a smaller set of covariates was used. For these analyses, only covariates that were significantly correlated with the dependent variable were included in the analyses.

Prior to the logistic regression analysis, the proportions of children who scored above the borderline cutpoint on the CBCL and TRF subscales were examined for each level of marijuana use. If the proportions for adjacent levels of marijuana use were similar, these categories were combined to increase the statistical power of testing. The sex problems, thought problems, and anxious/depressed T-scores of the CBCL and TRF were excluded from the analyses because there were too few children who scored above the clinical borderline score.

Although there were moderate correlations between trimesters in the rate of marijuana use (ranging from 0.5 to 0.7), the use of marijuana was not constant throughout pregnancy. The majority of women reduced their use as their pregnancy progressed. Separate regression analyses were run for each trimester of pregnancy to assess the effects of exposure at the different time periods.

As a final step, parsimonious path analytical models were used to estimate the relations among the significant variables and to identify the strengths of the direct and indirect pathways between prenatal marijuana exposure and the behavior problems that were found to be significant in the separate regression analyses. The software package LISREL 8 [26] was used to estimate the significance of the hypothesized structural relationships and the overall goodness of fit indices.

3. Results

3.1. Correlates of marijuana use

The prevalence of marijuana use during pregnancy and at 10 years is shown in Table 2. Before pregnancy, 51% of the women in the study cohort used marijuana and 21% used at the rate of one or more joints/day. The women decreased their use of marijuana during pregnancy. By the third trimester of pregnancy, 19% of the subjects reported using any marijuana and 5% reported using marijuana at the rate of one or more joints/day. Compared to the rates prior to pregnancy, a steady decline in marijuana use has been observed over time. At the 10-year follow-up, only 22% of the women reported smoking marijuana.

As shown in Table 3, women who used one or more joints of marijuana per day during the first trimester were significantly more likely to be single, African-American, more hostile, drink more alcohol, and use more illicit drugs (other than marijuana) than were women who did not use marijuana during the first trimester. Moderate to heavy marijuana users during the second trimester of pregnancy were significantly more likely to have less income, to be

Table 1

Variables included in the stepwise regression analyses and their correlations with prenatal marijuana use^a

	First trimester ^b	Second trimester ^b	Third trimester ^b
Current maternal socioeconomic status			
Education	−0.05	−0.04	−0.12
Work/School status (no = 0, yes = 1)	−0.12	−0.12	−0.10
Family income	−0.12	−0.08	−0.06
Ethnicity (African American = 0, Caucasian = 1)	−0.21	−0.12	−0.15
Presence of male in the household (no = 0, yes = 1)	−0.09	−0.07	−0.08
Current psychosocial characteristics			
Depression	0.02	0.03	0.06
Hostility	0.01	−0.02	0.03
Life events	0.08	0.05	0.07
Support from relatives	−0.08	−0.07	−0.04
Coping ability	0.01	0.00	0.04
Current child's home environment & characteristics			
HOME-SF	−0.10	−0.06	−0.07
FES conflict	0.03	0.03	0.00
Number of siblings	0.00	0.04	0.05
Maternal custody of the child (no = 0, yes = 1)	−0.10	−0.13	−0.14
Gender ^c	0.01	−0.05	−0.06
Age ^c	−0.10	−0.01	−0.03
Number of illnesses	−0.03	−0.05	−0.09
Number of injuries	−0.02	−0.09	−0.05
Number of hospitalizations	−0.05	−0.04	−0.03
Current maternal substance use			
Marijuana	0.35	0.26	0.19
Alcohol	0.06	0.04	0.04
Tobacco	0.02	0.05	0.01
Cocaine	0.18	0.12	0.09
Prenatal substance use			
Alcohol	0.20	0.09	0.29
Tobacco	0.05	0.06	0.05
Cocaine	0.11	0.05	0.03
Dependent variables			
SNAP inattention symptoms	0.13	0.04	0.10
SNAP hyperactivity symptoms	0.09	0.05	0.13
SNAP impulsivity	0.08	0.04	0.10
SNAP peer problems	0.07	0.05	0.09
CBCL internalizing T-scores	−0.04	−0.08	−0.02
CBCL externalizing T-scores	0.03	−0.01	0.00
TRF internalizing T-scores	−0.04	−0.03	−0.03
TRF externalizing T-scores	0.07	0.09	0.09

^a Correlations greater than 0.07 in their absolute values are significantly different than zero at $\alpha = 0.05$.^b Log transformed marijuana use.^c Used for SNAP outcomes only.

single, African-American, and drink more alcohol than were women who did not use marijuana during the second trimester. These same factors characterized moderate to heavy marijuana users at the third trimester of pregnancy. In addition, third trimester moderate to heavy users had significantly less education and smoked more cigarettes than abstainers.

The correlations between prenatal marijuana use and the covariates included in the analytical models were low to moderate (Table 1). At 10 years, the variables with the highest correlations with prenatal marijuana use were work/school status, maternal custody of the child, and current use of marijuana and cocaine.

3.1.1. Mother's report

The zero-order correlations between first and third trimester marijuana use and the SNAP subscales were signifi-

cantly different from zero (Table 1). First trimester marijuana use remained a significant predictor of the attention scale of the SNAP after controlling for other risk factors using stepwise multiple regression (coef. = 0.7, $p < 0.01$).

Table 2

Prevalence of marijuana use (%)

Time of assessment	None ^a	Light ^b	Moderate ^c	Heavy ^d	Total N
Year before pregnancy	49.1	20.2	9.8	20.9	635
First trimester	58.9	19.5	8.0	13.5	635
Second trimester	77.4	14.1	3.3	5.2	575
Third trimester	81.4	10.7	2.8	5.0	635
10 years	78.4	16.6	1.9	3.2	634

^a None = no use.^b Light = up to 0.4 joints/day.^c Moderate = from 0.4 to 0.89 joints/day.^d Heavy = More than 0.89 joints/day.

Table 3

Prenatal maternal characteristics associated with prenatal marijuana use

	Group 1 ADJ = 0 N = 374	Group 2 0 < ADJ ≤ 0.89 N = 175	Group 3 ^a ADJ > 0.89 N = 86	Significant group differences ^b
First trimester use				
Education (yrs)	11.9	11.9	11.7	
Married (%)	38	27	17***	
Work/School (%)	27	31	17	1 & 2, 1 & 3
Family income (% < \$400/mo)	59	63	70	
Race (% white)	54	46	20***	1 & 3, 2 & 3
Depression	40.6	41.0	41.9	
Hostility	18.2	19.0	19.8*	1 & 3
No. drinks/day	0.4	0.9	1.0**	1 & 2, 1 & 3
No. cigarettes/day	7.5	9.0	9.5	
Illicit drugs (%)	6	14	20***	1 & 2, 1 & 3
Second trimester use	Group 1 ADJ = 0 N = 445	Group 2 0 < ADJ ≤ 0.4 N = 81	Group 3 ADJ > 0.4 N = 49	
Education (yrs)	11.9	12.0	11.5	
Married (%)	38	21	18***	1 & 2, 1 & 3
Work/School (%)	15	16	8	
Family income (% < \$400/mo)	63	72	79*	1 & 3
Race (% white)	51	38	24***	1 & 2, 1 & 3
Depression	40.7	43.7	42.8**	1 & 2
Hostility	18.0	18.8	18.8	
No. drinks/day	0.1	0.21	0.21***	1 & 2, 1 & 3
No. cigarettes/day	7.9	10.2	9.1**	1 & 2
Third trimester use	Group 1 ADJ = 0 N = 517	Group 2 0 < ADJ ≤ 0.4 N = 68	Group 3 ADJ > 0.4 N = 50	
Education (yrs)	11.9	11.9	11.3**	1 & 3, 2 & 3
Married (%)	36	26	20*	1 & 3
Work/School (%)	18	19	16	
Family income (% < \$400/mo)	66	70	85*	1 & 3
Race (% white)	50	40	24***	1 & 3
Depression	40.3	40.9	42.9	
Hostility	17.6	18.0	19.3	
No. drinks/day	0.11	0.15	0.47***	1 & 2, 1 & 3
No. cigarettes/day	8.6	10.5	12.2***	1 & 3

^a Overall significance using large sample Kruskal-Wallis analysis of variance for the continuous variables and χ^2 test for the dichotomous variables: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

^b Significant at $\alpha = 0.05$ using Bonferroni Inequality for multiple comparisons.

Third trimester marijuana use was significantly associated with higher scores on the hyperactivity (coef. = 1.2, $p < 0.001$), attention (coef. = 0.9, $p < 0.01$), and impulsivity (coef. = 1.0, $p < 0.01$) scales of the SNAP.

A comparison of the means of the SNAP subscales across different levels of prenatal marijuana use supported the results of the regression analyses, although it indicated a nonlinear relationship between third trimester marijuana exposure and increased behavior problems. The average scores on the attention subscale of the SNAP among children of abstainers, light to moderate, and heavy first trimester users were 8.6, 9.1, and 9.7 [$F(2, 632) = 5.4$, $p = 0.005$], respectively. Children exposed in the third trimester to none, light, and moderate to heavy marijuana use scored on average 8.8, 8.7, and 10.2 [$F(2, 632) = 5.4$, $p = 0.005$] on

attention, 9.6, 9.6, and 10.9 [$F(2, 632) = 4.7$, $p = 0.01$] on hyperactivity, and 10.1, 9.9, and 11.4 [$F(2, 632) = 4.4$, $p = 0.01$] on the impulsivity scale of the SNAP, respectively. No other group comparison was significant. The regression analyses were repeated with the third trimester marijuana use dichotomized comparing moderate and heavy users to none and light users. As above, third trimester marijuana use dichotomized was a significant predictor of the attention (coef. = 1.3, $p < 0.001$), hyperactivity (coef. = 1.2, $p < 0.01$), and impulsivity (coef. = 1.2, $p < 0.01$) scales of SNAP.

Other variables that significantly predicted more problems on the SNAP subscales included male gender, African-American race, more child hospitalizations over the past year, more siblings, poorer environment as assessed by the HOME-SF, more maternal hostility and depression, less

maternal coping ability, and current maternal cigarette smoking. In addition, children who were not in maternal custody and children exposed to alcohol during the first trimester of pregnancy had more peer problems. The total amount of variability in the SNAP problem behavior scales that was explained by these predictors, including exposure to marijuana, ranged from 0.15 to 0.25.

Second trimester marijuana use was associated with fewer internalizing behavior problems on the CBCL and this association remained significant after adjusting for other covariates (coef. = -3.0 , $p < 0.05$). Number of child hospitalizations and illnesses over the past year, number of siblings, maternal hostility and depression, life events, family conflicts, current maternal tobacco use, and first trimester cocaine use were positively related to the CBCL internalizing and externalizing scales. Lower HOME-SF scores predicted more internalizing and externalizing problems on the CBCL. The total amount of variability explained by the predictors, including exposure to marijuana, for the CBCL scores ranged from 0.24 to 0.26.

The percentages of children who scored 67 or more (the borderline clinical range) on the CBCL subscales for each category of prenatal marijuana use are shown in Table 4. Children who were rated above and below the borderline clinical

range on the CBCL subscales were compared using logistic regression. Children who were exposed in the first trimester to heavy marijuana use had significantly higher scores on the delinquency scale of the CBCL. Twenty-six percent of the offspring of the first trimester heavy users scored above the borderline cutpoint compared to 15% and 13% among offspring of the light/moderate users and abstainers, respectively. After adjusting for other significant covariates, the relative risk of a child prenatally exposed to heavy marijuana use scoring above the cutoff score on the delinquency subscale was 2.4 times that of a child not exposed heavily to marijuana (C.I. = [1.3, 4.5]; $p < 0.01$). Prenatal marijuana use was not significantly associated with any other CBCL subscales.

We found significant relations between first trimester marijuana exposure and SNAP inattention symptoms and between first trimester marijuana exposure and CBCL delinquency. As a next step, we compared two competing models of the relations between prenatal marijuana exposure, inattention symptoms, and delinquency. Our first hypothesis was that behaviors such as inattention symptoms, because of their stability from early childhood to preadolescence, are more proximal to the exposure and would mediate the expression of other problem behaviors such as delinquency. A competing model assumed a significant direct

Table 4
Percent of children scoring above the borderline clinical cutoff score on the CBCL by levels of marijuana use

	Group 1 ADJ = 0 N = 374	Group 2 0 < ADJ ≤ 0.89 N = 175	Group 3 ^a ADJ > 0.89 N = 86	Significant group differences ^b
First trimester use				
Withdrawn	11	7	10	
Somatic complaints	12	15	9	
Social problems	12	9	9	
Attention problems	12	12	14	
Delinquent behavior	13	15	26**	1 & 3, 2 & 3
Aggressive behavior	7	8	10	
Second trimester use	Group 1 ADJ = 0 N = 445	Group 2 0 < ADJ ≤ 0.4 N = 81	Group 3 ADJ > 0.4 N = 49	
Withdrawn	11	7	6	
Somatic complaints	14	11	8	
Social problems	11	7	4	
Attention problems	12	10	16	
Delinquent behavior	14	16	24	
Aggressive behavior	8	7	8	
Third trimester use	Group 1 ADJ = 0 N = 517	Group 2 0 < ADJ ≤ 0.4 N = 68	Group 3 ADJ > 0.4 N = 50	
Withdrawn	10	9	6	
Somatic complaints	13	10	6	
Social problems	11	7	6	
Attention problems	12	13	12	
Delinquent behavior	15	18	16	
Aggressive behavior	7	15	4	

^a Overall significance using χ^2 test: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

^b Significant at $\alpha = 0.05$ using Bonferroni Inequality for multiple comparisons.

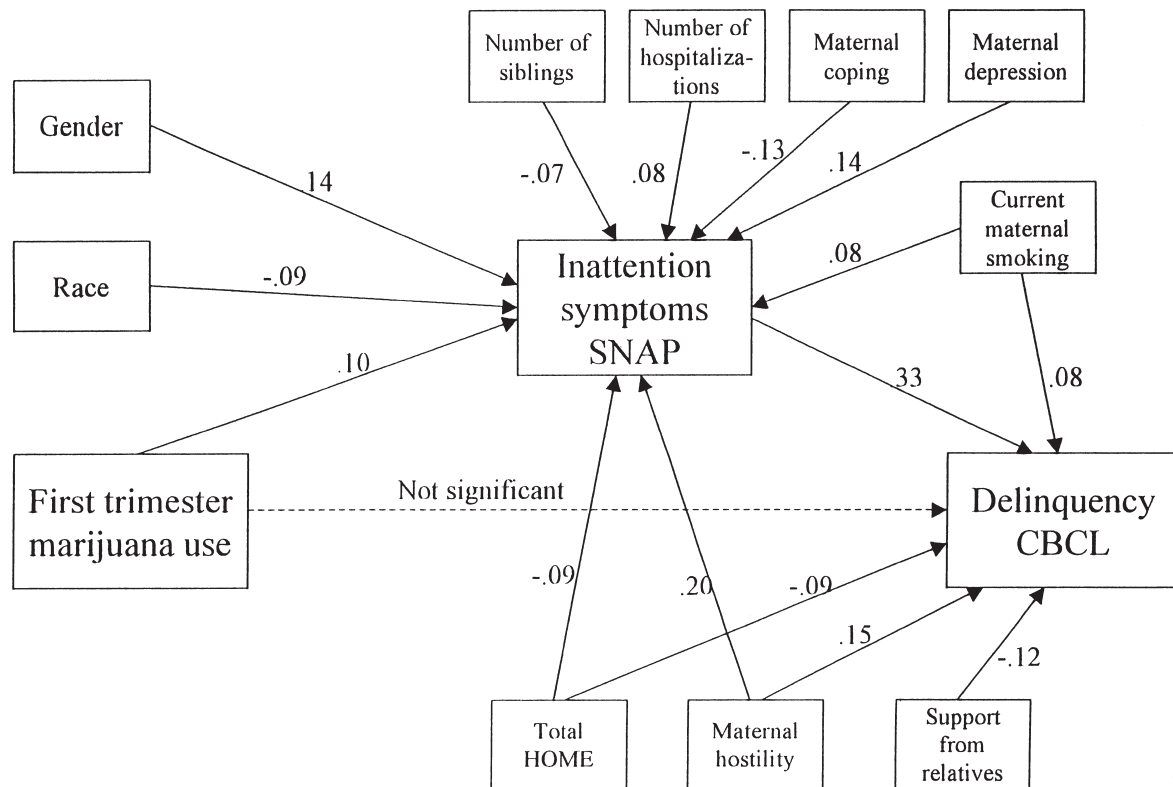


Fig. 1. Path analysis illustrating mediation effect of inattention symptoms between prenatal marijuana use and mothers' report of delinquency.

pathway between marijuana use and delinquency in addition to the indirect relationship between these two variables. These models were tested using structural equation modeling.

The standardized estimated coefficients are presented in Figure 1. The coefficients show the relative significance of each variable in predicting the child's behavior problems. First trimester marijuana exposure was significantly and directly related to increased inattention symptoms on the SNAP at age 10, and indirectly related to delinquency through the inattention symptoms. The chi-square goodness of fit test statistic was 9.5, which indicated a perfect data-model fit with 38 degrees of freedom. The path model was only tested for first trimester marijuana exposure because marijuana use in the second and third trimesters was not related to delinquency as measured by the CBCL.

3.1.2. Teacher's report

There were no significant linear relations between marijuana use and the TRF total, internalizing, and externalizing scales for any trimester of pregnancy after adjusting for other significant covariates. However, there were nonlinear relationships between second and third trimester marijuana use and the TRF externalizing score. As explained in the data analysis section, second and third trimester marijuana use were grouped into none, light, and moderate/heavy use. The mean TRF externalizing T-scores among abstainers, light, and moderate to heavy marijuana users were 53.4, 53.6, and 58.7 [$F(2, 517) = 4.3, p = 0.01$] for the second trimester

of pregnancy and 53.6, 54.6, and 59.2 [$F(2, 572) = 5.2, p = 0.006$] for the third trimester of pregnancy, respectively. The regression analyses were repeated with second and third trimester marijuana use categorized into two categories: (1) abstainer and light users and, (2) moderate and heavy users. In this analysis, second trimester marijuana use was significantly associated with the TRF externalizing score (coef. = 4.3, $p < 0.01$) and the total behavior problem score (coef. = 3.9, $p < 0.05$). Similarly, third trimester marijuana exposure was a significant predictor of the TRF externalizing score (coef. = 4.3, $p = 0.006$). Thus, for both second and third trimesters, a threshold was found. Above the level of approximately three joints/week in the second and third trimesters, prenatal exposure to marijuana predicted an increased rate of externalizing problems as noted by teachers on the TRF.

Other significant predictors of more behavior problems on the teacher's report included African-American race, lower total HOME-SF score, more child hospitalizations and injuries, less social support from relatives, and higher levels of maternal hostility. Children who were not in maternal custody were reported by the teachers to have more internalizing behavior problems. On average, prenatal marijuana exposure and these predictors explained 10% of the total variation in the TRF outcomes.

Second and third trimester marijuana use were each significant predictors of delinquency on the TRF when children who were rated above and below the borderline clinical range were compared (Table 5). The proportions of

Table 5

Percent of children scoring above the borderline clinical cutoff score on the TRF by levels of marijuana use

	Group 1 ADJ = 0 N = 339	Group 2 0 < ADJ ≤ 0.89 N = 163	Group 3 ^a ADJ > 0.89 N = 73	Significant group differences ^b
First trimester use				
Withdrawn	9	6	7	
Somatic complaints	7	8	3	
Social problems	10	6	5	
Attention problems	13	12	12	
Delinquent behavior	12	12	12	
Aggressive behavior	15	15	14	
Second trimester use	Group 1 ADJ = 0 N = 405	Group 2 0 < ADJ ≤ 0.4 N = 72	Group 3 ADJ > 0.4 N = 43	
Withdrawn	9	8	7	
Somatic complaints	7	4	7	
Social problems	8	6	9	
Attention problems	12	12	16	
Delinquent behavior	11	10	23*	1 & 3
Aggressive behavior	14	8	23	
Third trimester use	Group 1 ADJ = 0 N = 467	Group 2 0 < ADJ ≤ 0.4 N = 64	Group 3 ADJ > 0.4 N = 44	
Withdrawn	9	6	5	
Somatic complaints	8	3	2	
Social problems	9	5	5	
Attention problems	13	6	20	
Delinquent behavior	12	5	27**	1 & 3, 2 & 3
Aggressive behavior	14	9	27*	1 & 3, 2 & 3

^a Overall significance using χ^2 test: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.^b Significant at $\alpha = 0.05$ using Bonferroni Inequality for multiple comparisons.

children scoring above the borderline clinical cutoff for delinquency with respect to second trimester marijuana exposure were 11%, 10%, and 23% for abstainers, light, and moderate to heavy users, respectively. After controlling for other significant covariates, the offspring of moderate to heavy second trimester marijuana users were 2.3 times more likely to score above the borderline cutpoint score than were the offspring of abstainers and light users (C.I. = [1.02, 5.05]; $p = 0.04$). The proportions of delinquency scores above the borderline for third trimester marijuana exposure were 12%, 5%, and 27% for abstainers, light, and moderate to heavy users, respectively. After taking into account other significant predictors of delinquency, children exposed to moderate or heavy third trimester marijuana were three times more likely to score above the borderline clinical range on the delinquency scale than were children of abstainers and light users (C.I. = [1.4, 6.4]; $p < 0.01$). Prenatal marijuana use was not significantly related to any other subscale of the TRF.

In parallel to the CBCL analyses, we tested the mediating effect of SNAP attention problem scores on the relations between prenatal marijuana exposure and the TRF delinquency score. In this analysis, however, the concordance was between attention, delinquency, and third trimester exposure. Third trimester marijuana use was significantly and directly related to increased inattention symptoms on the

SNAP and indirectly related to delinquency as reported by the teachers (Fig. 2). The effects of third trimester exposure on delinquency were mediated by the effects of exposure on attention. The structural equation model fit the data perfectly. The chi-square goodness of fit was 3.6 with 38 degrees of freedom.

The structural equation model that was derived using the data from the TRF as an outcome was similar to the model that was developed using the CBCL measure of delinquency as an outcome. There were two exceptions. First, current maternal tobacco smoking was a significant predictor of the CBCL delinquency scale, but it was not a significant predictor of the TRF delinquency scale. Second, race was a significant predictor of the TRF delinquency scale, but not of the CBCL.

The analyses of the behavior problems reported by mothers and teachers were repeated excluding the 21 children who were taking medication for attention deficit hyperactivity disorder. The exclusion of these children did not alter the relations between prenatal marijuana use and behavior problems.

4. Discussion

Prenatal marijuana exposure in the first and third trimesters predicted significantly increased hyperactivity, inattention, and impulsivity symptoms among the exposed children at age 10, as reported by the mothers on the SNAP. These

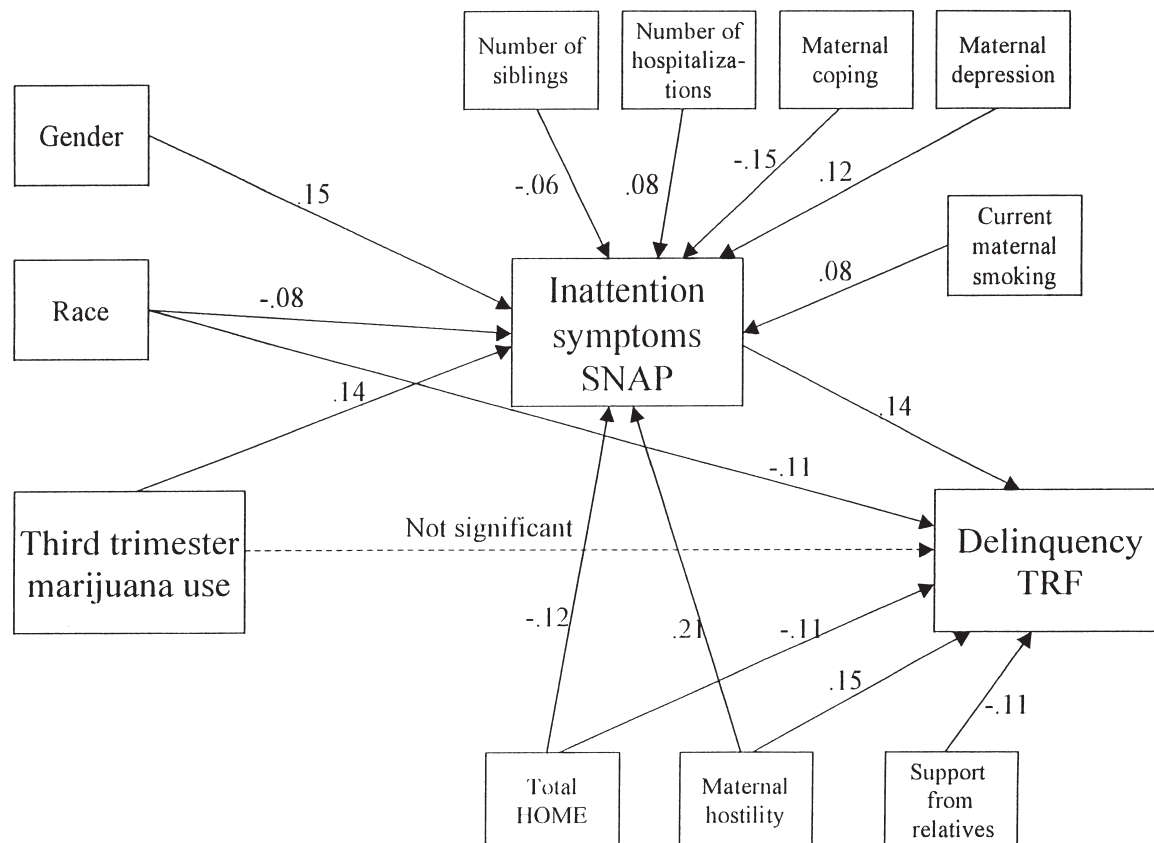


Fig. 2. Path analysis illustrating mediation effect of inattention symptoms between prenatal marijuana use and teachers' report of delinquency.

findings are similar to those reported by Fried et al. [20] in the Ottawa Prenatal Prospective Study, when the children were six years of age, using an averaged measure of marijuana use across pregnancy.

On the CBCL, a maternal rating of child behavior problems, there was a significant nonlinear association between prenatal marijuana exposure during the first trimester and increased rates of delinquency. Similar relations were found on the teachers' reports: Increased levels of delinquency and externalizing behavior problems were found among the children who were exposed to marijuana in the second and third trimesters of pregnancy. Thus, we have documented a consistent association using independent reports from both the mothers and the teachers.

These findings are also consistent with reports from this project when the children were 6 years old. At that age, second and third trimester marijuana exposures were significantly associated with delinquency scores on the TRF [8]. The findings also parallel the report by O'Connell and Fried [31], who found that children exposed prenatally to marijuana had a higher rate of conduct disorder. In their sample, however, this difference was not significant after controlling for extraneous variables. These findings are not consistent by trimester of exposure, although there is a consistent

overall relation between exposure during pregnancy and increased rates of delinquency. The difference by trimester may be associated with the fact that children exposed in the second and third trimesters were exposed throughout pregnancy and were more heavily exposed. The more affected children would have been more likely to be identified by their teachers.

One result was not in the predicted direction. Second trimester marijuana exposure was associated with fewer internalizing problems on the CBCL. This finding was not replicated on the teachers' reports. In a separate analysis of these data, prenatal marijuana exposure during each trimester of pregnancy was related to higher levels of depression as reported by the children [24]. There was, however, a very low correlation between the report of depression by the mother on the CBCL and the children's self-reports. The fact that mothers are not accurate observers of internalizing symptoms among their children has been reported in previous studies [17, 28, 42].

The association between attention problems and delinquency has been reported by several researchers in the child development literature [21, 35, 36, 44]. Based on this literature, we hypothesized that inattention symptoms would mediate the relation between prenatal marijuana exposure and

delinquency. This was found to be the case using the reports of delinquency from both the mothers' and the teachers' evaluations. On both measures, inattention symptoms mediated the effect of prenatal marijuana exposure on delinquency. With inattention symptoms in the model, there was no significant direct effect of prenatal marijuana exposure on delinquency. With the exception of race, which only entered the model using the teacher's report, the other predictors of delinquency were very similar between the two models, an indication that the mothers and the teachers were reporting on similar constructs.

There are alternative explanations for the relations between gestational marijuana exposure, attention, and delinquency. Although we controlled for the known covariates of these outcomes, it is possible that we did not control for one or more factors that may confound the relationship. For example, women who use marijuana may themselves have behavioral problems that could include attention deficits or antisocial behaviors. Our analyses illustrate a potential pathway by which prenatal marijuana exposure leads to the development of child behavior problems.

In summary, this study demonstrated a significant relationship between prenatal marijuana exposure and offspring behavior problems at age 10, after controlling for a large number of covariates such as maternal depression, home environment, social support, and exposure to tobacco, alcohol, and other illicit drugs. The sample represented an equal number of Caucasian and African-American women of lower socioeconomic status who attended a prenatal clinic. It would be interesting to see if the results are reproducible in a cohort with higher economic status. We are following these children into adolescence to determine if these relationships persist.

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