Original Investigation

Association between smoking and retrospectively reported attention-deficit/hyperactivity disorder symptoms in a large sample of new mothers

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Abstract

Introduction: This study investigated the association between retrospectively reported attention-deficit/hyperactivity disorder (ADHD) symptoms experienced during childhood and five cigarette smoking–related outcomes in adulthood.

Methods: A large sample ($N=1,117$) of new mothers participating in an ongoing longitudinal study completed retrospective reports of their childhood ADHD symptomatology, as well as concurrent and retrospective reports of their smoking behavior. Linear regression models tested the association between ADHD symptomatology and smoking outcomes.

Results: Childhood ADHD symptomatology was predictive of the number of cigarettes smoked per day currently and during pregnancy, as well as the age at onset of smoking. We found nonlinear associations between hyperactive–impulsive symptoms and the number of cigarettes smoked per day in pregnancy, as well as between inattentive symptoms and the number of cigarettes smoked per day currently. Women who retrospectively reported intermediate levels of ADHD symptoms during their childhood reported smoking more cigarettes per day than women who reported low or high levels of ADHD symptoms during childhood. We also found multiplicative relationship between inattentive and hyperactive–impulsive symptoms, such that inattentive symptoms were predictive of an earlier age at smoking onset only when hyperactive–impulsive symptoms were low; moreover, the magnitude of this association was stronger for Black relative to White women.

Discussion: These findings demonstrate the importance of considering differential effects of ADHD symptoms and smoking outcomes as a function of sex and race. They also represent a potentially indirect means through which women who have even a moderate childhood history of ADHD symptomatology may create a set of circumstances that compromise the health and well-being of their own children.

Introduction

Individuals with attention-deficit/hyperactivity disorder (ADHD) smoke significantly more than the general population or nondiagnosed control subjects (Lambert & Hartsough, 1998; Milberger, Biederman, Faraone, & Chen, 1997; Milberger, Biederman, Faraone, Chen, & Jones, 1997; Molina & Pelham, 2003; Pomerleau, Downey, Stelson, & Pomerleau, 1995; Rhode, Kahler, Lewinsohn, & Brown, 2004). Moreover, ADHD patients report earlier smoking initiation than nondiagnosed peers and are more likely to progress from initiation to regular smoking (Molina & Pelham, 2003; Rhode et al., 2004). Adult smokers with ADHD also report more difficulty quitting than individuals in the general population (Pomerleau et al., 1995).

Although studies have reported that the association between ADHD and substance use is often accounted for by the presence of comorbid conduct disorder (Barkley, Fischer, Edelbrock, & Smallish, 1990; Biederman et al., 1997; Boyle & Offord, 1991), ADHD has been shown to be an independent risk factor for tobacco use, even after controlling for conduct disorder (Milberger, Biederman, Faraone, Wilens, & Chu, 1997; Molina & Pelham, 2003). Evidence also indicates that problems with inattention and executive functioning predict smoking, even after controlling for conduct problems (Aytaclar, Tarter, Kirisci, & Lu, 1999; Burke, Loeber, & Lahey, 2001; Molina & Pelham, 2003). Further, smoking risk is more strongly associated with the number of inattentive symptoms than with the diagnosis of ADHD itself (Burke et al., 2001).

The relationship between smoking and inattention is also supported by studies using non-ADHD samples. In smokers enrolled in a smoking cessation program, ADHD inattentive-type symptoms were associated with smoking motivation factors (Lerman et al., 2001). Data from a community sample of adolescents also showed that inattentive symptoms predicted smoking status (Tercyak, Lerman, & Audrain, 2002). Several larger community studies as well as human and nonhuman laboratory

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studies also suggest that nicotine self-administration (i.e., smoking) may be related to its augmenting effects on attention and executive functioning (Levin et al., 1998; Levin & Simon, 1998; Rezvani & Levin, 2001).

We have reported on the association between retrospectively reported ADHD symptoms and smoking outcomes in a population-based sample of young adults while controlling for the confounding effects of conduct disorder symptoms, gender, socioeconomic status, and ethnicity (Kollins, McClernon, & Buemmel, 2005). The same study reported a linear relationship between self-reported inattentive and hyperactive-impulsive symptoms and smoking outcomes. Also, among individuals reporting lifetime smoking, ADHD symptoms decreased the estimated age at smoking onset and increased the number of cigarettes smoked. Finally, the study found that hyperactive-impulsive symptoms independently predicted risk for lifetime smoking, even when inattentive symptoms were controlled; however, inattentive symptoms failed to predict lifetime smoking when hyperactive-impulsive symptoms were controlled (Kollins et al., 2005). The finding that hyperactive-impulsive symptoms were better predictors of lifetime regular smoking was at odds with previous studies that have reported stronger associations between inattentive symptoms and smoking outcomes (Aytaclar et al., 1999; Burke et al., 2001; Molina & Pelham, 2003; Tercyak et al., 2002). However, comparisons across studies are difficult given differences with respect to the definition of smoking outcomes, the age of participants, and the proportion of the sample that was male.

To date, the influence of sex on the association between ADHD and smoking has not been evaluated fully. The studies that did include equal proportions of males and females either treated the sex of participants as a confounder variable (Kollins et al., 2005) or used it solely for descriptive purposes (Tercyak et al., 2002). However, understanding whether the relationship between ADHD and subsequent smoking outcomes holds for females—and particularly females who are pregnant or are primary caregivers to young children—has important public health implications. For example, both prenatal and postnatal exposure to maternal smoking are known to have a range of adverse outcomes on children (Ernst, Moolchan, & Robinson, 2001; Eskenazi & Castorina, 1999; Eskenazi & Trupin, 1995; Wakschlag, Pickett, Cook, Benowitz, & Leventhal, 2002; Weitzman, Byrd, Aligne, & Moss, 2002). To this end, the present study examined the association between retrospectively reported ADHD symptoms and smoking behaviors in a sample of women who recently gave birth. We were specifically interested in whether retrospectively reported childhood ADHD symptoms predicted smoking during and following pregnancy.

Methods

Study design

The Family Life Project (FLP) is an ongoing study of a representative sample of children who were born in two areas of rural poverty: northern Appalachia (Pennsylvania) and eastern North Carolina. Details of the study are provided elsewhere (Vernon-Feagans et al., 2008). Briefly, recruitment occurred in six counties (three in each state), 7 days/week from September 2003 through September 2004 using a standardized script and screen-

ing protocol. The final sample consisted of 1,292 families. Low-income and Black families were oversampled, though complex sampling procedures permit generalizations back to the larger population of children born in these counties during this time period.

Sample

The present study is based on 1,116 women who were the biological mothers of study children who participated in a home visit when target children were approximately 24 months of age.

Procedure

Following recruitment, families were visited in their homes when children were approximately 2, 6, 15, and 24 months of age. All the data included in this study were collected at the 24-month visit. At each home visit, caregivers completed questionnaires and interviews and completed a series of observational tasks. At their first home visit, caregivers completed the Kaufman Functional Academic Skills Test literacy screener (Kaufman & Kaufman, 1994). Caregivers who read at an eighth-grade reading level (or beyond) completed questionnaires on their own (81% of total sample), whereas questionnaires were read to those reading below an eighth-grade reading level (19% of total sample).

Measures

Demographic data. Caregivers provided information on household composition, as well as demographic information including race, income, and job status of other household members.

Income-needs ratio. Caregivers provided information about household income. An annual household total income figure was created and divided by the 2004 U.S. federal poverty threshold that corresponded to the family size and composition to create the income-needs ratio.

Brief Symptom Index. The Brief Symptom Index (BSI; Derogatis & Melisaratos, 1983) is a self-report screening index of mental health functioning. In the present study, caregivers completed the depression ($\alpha = .86$), anxiety ($\alpha = .82$), and hostility ($\alpha = .82$) subscales.

Attention-deficit/hyperactivity disorder. Mothers of target children retrospectively rated the presence of *Diagnostic and Statistical Manual of Mental Disorders* (fourth edition) (DSM-IV) ADHD symptoms when the children were 5–12 years of age. Each symptom was rated on a 4-point scale (0 = not at all, 1 = just a little, 2 = pretty much, and 3 = very much). Symptom counts were generated separately for inattentive and hyperactive-impulsive scales. A symptom was considered present if it was experienced “pretty much” or “very much.” This approach to dichotomizing symptoms has been used previously and is considered clinical convention (Murphy & Gordon, 1998). Moreover, internal consistencies (i.e., Kuder-Richardson formula 20, KR-20) of the resulting inattentive and hyperactive-impulsive symptom count scales were good (inattentive KR-20 = 0.87, hyperactive-impulsive KR-20 = 0.80). Symptom counts also were used to classify participants into four mutually exclusive groups that corresponded to DSM-IV ADHD subtypes. Participants with inattentive and hyperactive-impulsive scores of at least 6 were classified as combined type (COT), those with inattentive but not

hyperactive-impulsive scores of at least 6 as inattentive-only type (IOT), and those with hyperactive-impulsive but not inattentive scores of at least 6 as hyperactive-impulsive-only type (HIT). Those with inattentive and hyperactive-impulsive scores of less than 6 were classified as a nonsymptomatic reference group.

Smoking. Six questions were asked regarding smoking behavior. The first question asked, "Have you ever smoked a cigarette?" (yes/no). Participants who responded no skipped subsequent questions. The second question asked, "About how old were you when you had your first cigarette?" The third question asked, "During your pregnancy with [target child's name], how often did you smoke cigarettes?" and had six response options (not at all, less than 1 day/week, 1–2 days/week, 3–5 days/week, almost every day, and every day). Participants who chose "1–2 days/week" or more frequently were classified as having smoked during pregnancy. The fourth question, which was asked only of participants who reported smoking 1–2 days/week or more during pregnancy, asked, "During your pregnancy with [target child's name], how many cigarettes did you smoke each day, on the average?" This question had six response options (less than 1 cigarette, 1–5 cigarettes, 6–15 [half a pack], 16–25 [about one pack], 26–35 [one and a half packs], and 2 packs or more). These responses were recoded into an estimated number of cigarettes smoked per day (0, 5, 10, 20, 30, and 40). The fifth question asked, "During the past 30 days, how often did you smoke cigarettes?" and had the same six response options as the third question. Participants who chose "almost every day" or "every day" were classified as daily smokers. The sixth question, which was asked only of participants who reported smoking 1–2 days/week or more, asked, "During the past 30 days, how many cigarettes did you smoke each day, on the average?" This question had the same six response options as the fourth question, and responses were recoded in an identical manner.

Data analyses

The goal of the analysis was to test whether retrospectively reported ADHD symptoms predicted five smoking outcomes—being a daily smoker, smoking during pregnancy, age at first cigarette (among daily smokers), and average number of cigarettes per day both currently (among daily smokers) and during pregnancy. Logistic regression was used to predict daily smoking and smoking during pregnancy. Linear regression models were estimated to predict the age at first smoking and the number of cigarettes smoked per day currently and during pregnancy. Two sets of models were estimated for each outcome. The first set included ADHD symptoms as continuous scores. These models differed with respect to how ADHD symptoms were used, including consideration of possible multiplicative (i.e., interaction between inattentive and hyperactive-impulsive symptoms) or quadratic (i.e., linear and squared terms for both inattentive and hyperactive-impulsive symptoms) effects, as well as whether ADHD symptom effects (i.e., main, multiplicative, or quadratic effects) were moderated by race. Examination of race as a moderator was exploratory and was intended to take advantage of the nearly equal proportions of White and Black women in the sample. Substantively, consideration of race as a moderator tested whether the strength of the association between ADHD symptoms and smoking outcomes differed by race. Nonsignificant interaction terms were eliminated, and models rerun where appropriate. Significant interactions were probed using techniques described by Aiken and West (1991).

Only final models are reported. The second set of models used three dichotomous dummy variables to represent ADHD subtypes (COT, HIT, IOT), with the nonsymptomatic group serving as the reference.

All models shared a common set of covariates. Age and income were included to allow for the possibility that younger and lower income mothers would be more likely to smoke, to have initiated smoking earlier, or to smoke more per day. State of residence and race were included to represent the sampling design, as well as to represent the possibility of geographic or racial differences in smoking behavior. Self-reports of current mental health functioning from the BSI were included to help guard against the possibility that current symptomatology might bias retrospective reports of ADHD or reports of smoking behavior. Graphical procedures (visualization of Cook's *D* values) were used to screen outliers for all models.

Results

Sample description

The total FLP sample consisted of 1,292 families (1,287 had a biological mother as the primary caregiver). The present study is based on 1,116 biological mothers who participated in a home visit when target children were approximately 24 months of age, at which time maternal ADHD symptomatology and smoking outcomes were assessed. A comparison of demographic characteristics at study entry (i.e., at the initial home visit, when target children were 2 months old) between the 1,116 biological mothers who participated in the 24-month home visit and the 176 biological mothers who did not revealed few differences. Specifically, at study entry, participating mothers did not differ from nonparticipating mothers with respect to race (40% White vs. 41% Black; $\chi^2_1, p = .89$), marital status (47% unmarried vs. 51% married; $\chi^2_1, p = .36$), or having a high school/General equivalency degree or better (81% vs. 78%; $\chi^2_1, p = .41$). However, participating mothers were more likely than nonparticipating mothers to live in Pennsylvania (41% vs. 33%; $\chi^2_1, p = .03$) and to have a 4-year college degree or better (15% vs. 8%; $\chi^2_1, p = .01$).

Descriptive statistics for the study sample are summarized in Table 1. The population is racially diverse (41% Black) and primarily working class. For example, 33% of women resided in households that were at or below the federal poverty line and 66% resided in households that were at or below twice the federal poverty line. Self-reported depression, anxiety, and hostility were consistent with BSI normative data. On average, respondents retrospectively reported less than one inattentive and one hyperactive-impulsive symptom, though 5.6% of the participants endorse at least six inattentive and/or hyperactive-impulsive symptoms (1.5% COT, 1.3% HIT, and 2.8% IOT). Table 1 also provides descriptive statistics for the subset of women who reported smoking during pregnancy ($n = 195$) and/or being a current daily smoker ($n = 281$). A total of 85% of women who reported smoking during pregnancy identified themselves as current daily smokers.

Distribution of ADHD symptoms

Given the central importance of ADHD symptom counts, we considered their distribution for the total sample, as well as separately for Black and White women (see Table 2). The distributions of ADHD symptom counts were positively skewed.

Table 1. Descriptive statistics

Characteristics	Total sample (<i>N</i> = 1,117)		Current daily smoker (<i>n</i> = 281)	Smoked in pregnancy (<i>n</i> = 195)
	<i>n</i>	%	%	%
Ever smoked	1,104	65.8	100	100
Smoke daily	1,104	25.5	100	84.6
Smoked in pregnancy	1,104	17.7	58.7	100
State (Pennsylvania)	1,117	41.5	54.1	55.9
Black	1,117	40.6	27.4	26.7
ADHD inattentive type	1,096	2.8	3.6	3.6
ADHD hyperactive-impulsive type	1,096	1.3	1.1	0.5
ADHD combined type	1,096	1.5	2.5	2.6
	<i>n</i>	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)
Age (years)	1,117	27.7 (5.8)	25.9 (4.8)	26.2 (4.7)
Income-needs ratio ^a	1,117	2.0 (2.7)	1.5 (1.3)	1.4 (1.3)
BSI depression (<i>T</i> score)	1,097	50.6 (9.4)	52.3 (9.9)	52.5 (9.9)
BSI anxiety (<i>T</i> score)	1,097	47.3 (9.9)	49.3 (10.7)	49.8 (10.7)
BSI hostility (<i>T</i> score)	1,097	50.4 (10.7)	52.8 (11.1)	52.3 (10.8)
Number of IN symptoms	1,096	0.7 (1.7)	0.9 (1.9)	1.0 (2.0)
Number of HI symptoms	1,096	0.8 (1.6)	1.0 (1.8)	1.1 (1.8)
Age at first cigarette (years)			14.7 (3.2)	14.2 (3.0)
Number of cigarettes per day (current)			14.1 (9.4)	15.9 (9.8)
Number of cigarettes per day (pregnancy)				8.5 (7.0)

Note. ADHD, attention-deficit/hyperactivity disorder; BSI, Brief Symptom Index; IN, inattentive; and HI, hyperactive-impulsive.

^aFor point of reference, an income-needs ratio of 2.0 corresponds to \$38,314/year for a family of four with two children under the age of 18 years.

However, given the large sample size, a reasonably large number of women endorsed six or more inattentive symptoms (*n* = 47) or six or more hyperactive-impulsive symptoms (*n* = 30). This helped to ensure that we had information along the full range of ADHD symptoms to inform potential effects on smoking outcomes. Black and White women did not differ in the number of inattentive, $t(1,093) = -0.91$, $p = .36$, or hyperactive-impulsive, $t(1,093) = -0.48$, $p = .63$, symptoms that they retrospectively recalled.

Smoked during pregnancy

These models predicted the likelihood of smoking during pregnancy among the total sample of women who had complete

data for all predictors (*n* = 192/1,090; see Table 3). Older women (odds ratio [OR] = 0.96, $p = .0099$), Black women (OR = 0.42, $p = .0003$), and women in higher income households (OR = 0.66, $p < .0001$) were all less likely to have reported smoking during pregnancy. In contrast, women who resided in Pennsylvania (OR = 1.58, $p = .03$) were more likely to have smoked during pregnancy. ADHD symptoms were not predictive of smoking during pregnancy. When ADHD was represented categorically as subtypes, the effects of demographic factors were largely unchanged (see Table 3). We found no evidence that women with ADHD subtypes were at increased risk for smoking during pregnancy, relative to the nonsymptomatic comparison group.

Number of cigarettes per day during pregnancy

The next models predicted number of cigarettes smoked daily during pregnancy for women who had complete data for all predictors (*n* = 192; see Table 3). Black women (unstandardized regression coefficient [beta] [*b*] = -4.96, $p = .0005$) and those residing in higher income households ($b = -0.80$, $p = .04$) reported smoking significantly fewer cigarettes per day during pregnancy. There was a trend for women reporting higher current levels of depression ($b = 0.13$, $p = .06$) to report smoking more cigarettes per day during pregnancy. With respect to ADHD symptoms, we found significant linear ($b = 1.28$, $p = .019$) and quadratic ($b = -0.26$, $p = .028$) effects for hyperactive-impulsive symptoms (see Figure 1). The top panel of Figure 1 represents the relationship between hyperactive-impulsive symptoms and number of cigarettes per day during pregnancy. Women reporting intermediate levels of hyperactive-impulsive (i.e., 2–7) symptoms reported smoking the greatest number of cigarettes per day. To more fully understand this result, we estimated the model again

Table 2. Distribution of ADHD symptom counts

Sample	Subtype	<i>M</i> (<i>SD</i>)	Number of endorsed symptoms (%) ^a									
			0	1	2	3	4	5	6	7	8	9
White	IN	0.7 (1.7)	78	9	4	2	1	1	1	1	1	1
	HI	0.8 (1.6)	70	13	6	4	3	2	1	1	0	0
Black	IN	0.8 (1.6)	72	10	6	5	2	1	3	0	0	1
	HI	0.8 (1.5)	63	18	7	5	3	2	0	1	0	0
Total sample	IN	0.7 (1.7)	75	9	5	3	2	1	2	1	1	1
	HI	0.8 (1.6)	67	15	6	4	3	2	1	1	0	0

Note. Total sample = 1,116 (Black = 443, White = 663); ADHD, attention-deficit/hyperactivity disorder; IN, inattentive; and HI, hyperactive-impulsive.

^aFrequencies may not sum to 100% due to rounding error.

Table 3. Prediction of smoking status and quantity of cigarettes smoked per day during pregnancy

	Smoked in pregnancy (<i>n</i> = 192/1,090)		Cigarettes smoked per day (<i>n</i> = 192)	
	OR (95% CI)	OR (95% CI)	<i>b</i> (SE)	<i>b</i> (SE)
Current age (years)	0.96** (0.93–0.99)	0.96** (0.93–0.99)	0.15 (0.10)	0.07 (0.10)
Race (Black)	0.42*** (0.26–0.67)	0.42*** (0.27–0.68)	–4.96 (1.39)**	–4.62 (1.35)**
State (Pennsylvania)	1.58* (1.04–2.40)	1.59* (1.04–2.42)	0.40 (1.16)	0.13 (1.14)
Income–needs ratio	0.66*** (0.57–0.77)	0.68*** (0.59–0.80)	–0.80 (0.40)*	–0.71 (0.39)+
Depression	1.01 (0.98–1.03)	1.00 (0.98–1.03)	0.13 (0.07)+	0.10 (0.07)
Anxiety	1.02 (1.0–1.05)	1.02 (1.0–1.05)	–0.09 (0.07)	–0.05 (0.06)
Hostility	1.00 (0.98–1.02)	1.00 (0.98–1.02)	–0.08 (0.06)	–0.02 (0.06)
IN (symptoms)	1.01 (0.90–1.14)		0.19 (0.32)	
HI (symptoms)	1.01 (0.89–1.50)		1.28 (0.54)*	
HI × HI			–0.26 (0.12)*	
IN type		0.98 (0.40–2.41)		3.46 (2.61)
HI type		0.25 (0.03–2.03)		–5.17 (6.49)
CO type		1.11 (0.36–3.46)		–0.14 (2.94)
<i>R</i> ²	0.14	0.14	0.10	0.06

Note. OR, odds ratio; *b*, unstandardized regression coefficient (beta); IN, inattentive; HI, hyperactive–impulsive; and CO, combined. The maximum rescaled *R*² is reported for the logistic regression model predicting smoking during pregnancy, whereas the more traditional adjusted (for the number of predictors) *R*² is reported for the linear regression models predicting the number of cigarettes smoked per day during pregnancy.

+*p* < .10, **p* < .05, ***p* < .01, ****p* < .0001.

with linear and quadratic terms for hyperactive–impulsive replaced by a five-level categorical variable that represented the number of retrospectively reported hyperactive–impulsive symptoms (i.e., 0–1, 2–3, 4–5, 6–7, 8–9). Least squares means (adjusted for all other terms in the model) are plotted in the bottom panel of Figure 1. Consistent with the association of symptoms in the top panel, women in the intermediate hyperactive–impulsive symptom groups (i.e., 2–5 symptoms) reported the highest levels of daily smoking during pregnancy relative to women who reported lower (i.e., 0–1) or higher (i.e., 6–9) levels of symptoms. When ADHD was represented categorically, the effects of race and household income were largely unchanged. Moreover, we found no indication that women with ADHD subtypes differed relative to the nonsymptomatic group with respect to the amount of daily smoking during pregnancy. Sensitivity analyses, in which the level of smoking during pregnancy was represented as an ordinal variable in cumulative logit models, resulted in an identical set of conclusions.

Current daily smoker

These models predicted the likelihood of current smoking among the total sample of women who had complete data (*n* = 279/1,090; see Table 4). Maternal age (*OR* = 0.92, *p* < .0001), being Black (*OR* = 0.35, *p* < .0001), and residing in a lower income household (*OR* = 0.72, *p* < .0001) were associated with lower rates of daily smoking. In contrast, women endorsing higher current levels of hostility (*OR* = 1.02, *p* = .01) were more likely to be daily smokers. We found a trend for women who resided in Pennsylvania (*OR* = 1.40, *p* = .07) to be more likely to be daily smokers. We found no evidence that ADHD symptoms increased the likelihood of being a daily smoker. Although we found evidence for a significant two-way interaction involving race and inattentive symptom count in the prediction of daily smoking, the simple relationship between inattentive symptoms and being a daily smoker was not significant for either group.

Figure 1. Model-implied relationship between hyperactive–impulsive symptom counts (top) and groups (bottom) with the number of cigarettes smoked per day during pregnancy.

Table 4. Prediction of daily smoking status, age first smoked, and quantity of cigarettes smoked per day (among daily smokers)

	Daily smoker ($n = 279/1,090$)		Cigarettes smoked per day ($n = 276$)		Age first smoked ($n = 279$)	
	OR (95% CI)	OR (95% CI)	b (SE)	b (SE)	b (SE)	b (SE)
Current age (years)	0.92*** (0.90–0.95)	0.92*** (0.90–0.95)	0.29* (0.12)	0.27* (0.12)	0.06 (0.04)	0.05 (0.04)
Race (Black)	0.35*** (0.23–0.53)	0.36*** (0.24–0.54)	–5.05** (1.54)	–4.96** (1.55)	2.26*** (0.53)	2.86*** (0.50)
State (Pennsylvania)	1.40* (0.97–2.03)	1.41* (0.97–2.04)	–2.33* (1.30)	–2.33* (1.32)	–0.56 (0.41)	–0.55 (0.42)
Income–needs ratio	0.72*** (0.64–0.82)	0.74*** (0.66–0.84)	–1.22** (0.45)	–1.37** (0.46)	0.20 (0.14)	0.26* (0.15)
Depression	1.00 (0.98–1.02)	1.00 (0.98–1.02)	0.14* (0.08)	0.13 (0.08)	0.01 (0.03)	0.02 (0.03)
Anxiety	1.01 (0.99–1.03)	1.01 (0.99–1.03)	–0.06 (0.08)	–0.04 (0.08)	–0.02 (0.02)	–0.03 (0.02)
Hostility	1.02* (1.01–1.04)	1.02* (1.00–1.04)	0.04 (0.07)	0.07 (0.07)	–0.03 (0.02)	–0.04 (0.02)
IN (symptoms)	1.01 (0.90–1.11)		2.74** (0.75)		–0.36* (0.17)	
HI (symptoms)	0.97 (0.86–1.09)		–0.49 (0.47)		–0.04 (0.18)	
IN $\times$ HI					0.08* (0.04)	
IN $\times$ IN			–0.44** (0.14)			
Black $\times$ IN					–0.44 (0.37)	
Black $\times$ HI					–0.51 (0.35)	
Black $\times$ IN $\times$ HI					0.29** (0.11)	
IN type		1.01 (0.44–2.29)		2.69 (2.90)		–0.88 (0.93)
HI type		0.60 (0.15–2.30)		–7.33 (6.46)		0.94 (1.70)
CO type		1.08 (0.37–3.17)		–2.97 (4.10)		1.25 (1.12)
R^2	0.18	0.17	0.09	0.05	0.24	0.20

Note. OR, odds ratio; b , unstandardized regression coefficient (beta); IN, inattentive; HI, hyperactive–impulsive; and CO, combined. The maximum rescaled R^2 is reported for the logistic regression model predicting smoking during pregnancy, whereas the more traditional adjusted (for the number of predictors) R^2 is reported for the linear regression models predicting the number of cigarettes smoked per day during pregnancy.

* $p < .10$, ** $p < .05$, *** $p < .01$, **** $p < .0001$.

Hence, this effect is not reported. When ADHD was represented categorically, the above effects were largely unchanged (see Table 4). Moreover, we found no evidence that ADHD subtypes increased women's risk for being a daily smoker, relative to the nonsymptomatic comparison group.

Number of cigarettes per day currently

The next models predicted the number of cigarettes smoked per day among women who reported being daily smokers and who had complete data ($n = 276$; see Table 4). Older women ($b = 0.29$, $p = .01$) reported smoking more cigarettes per day. Women who were Black ($b = -5.05$, $p = .0012$), who resided in a higher income household ($b = -1.22$, $p = .0076$), or who resided in Pennsylvania ($b = -2.33$, $p = .07$) currently smoked fewer cigarettes per day. In contrast, we found a trend for women who reported higher levels of current depression ($b = 0.14$, $p = .07$) to currently smoke more cigarettes per day. With respect to ADHD symptom counts, we found significant linear ($b = 2.74$, $p = .0003$) and quadratic ($b = -0.44$, $p = .0012$) effects for inattentive symptoms. Figure 2 depicts the nature of this interaction. The top panel of Figure 2 represents the relationship between inattentive symptoms and daily smoking. Women who reported intermediate levels of inattentive (i.e., 2–7) symptoms reported smoking the greatest number of cigarettes per day. To more fully understand the nature of this result, we estimated the model again with linear and quadratic terms for inattentive replaced by a five-level categorical variable that represented the number of retrospectively reported inattentive symptoms (i.e., 0–1, 2–3, 4–5, 6–7, 8–9). Least squares means (adjusted for all other terms in the model) are plotted in the bottom panel of Figure 2. Consistent with the association of symptoms in the top panel, wom-

en in the intermediate inattentive symptom groups (i.e., 2–7 symptoms) reported the highest levels of cigarettes per day relative to women who reported 0–1 or 8–9 symptoms. When ADHD was represented categorically, the effects of covariates were largely unchanged. Moreover, we found no indication that women with ADHD subtypes differed relative to the nonsymptomatic group with respect to the number of cigarettes currently smoked per day. Sensitivity analyses, in which the level of daily smoking was represented as an ordinal variable in cumulative logit models, resulted in an identical set of conclusions.

Age at first cigarette

These models predicted the age at first cigarette smoking for the women who reported being currently daily smokers and who had complete data ($n = 279$; see Table 4). Although a main effect indicated that Black women ($b = 2.26$, $p < .0001$) reported smoking their first cigarette at a later age, this finding was qualified by a significant three-way interaction involving race, inattentive, and hyperactive–impulsive symptoms ($b = 0.29$, $p = .009$). Figure 3 depicts the nature of this interaction. To be clear, in Figure 3, low and high levels of ADHD symptoms were defined as being 1 SD below or above the mean of ADHD symptoms. “Low” and “high” groups were defined solely for purposes of depicting the relationship graphically—continuous symptoms scores were used when estimating models. Increasing levels of inattentive symptoms were not significantly related to an earlier age at first smoking in the presence of higher levels of hyperactive–impulsive symptoms for White ($b = -0.2$, $p = .11$) or Black ($b = -0.1$, $p = .63$) women. In contrast, increasing levels of inattentive symptoms were significantly related to an earlier age at first smoking in the presence of lower levels of hyperactive–impulsive symptoms

Figure 2. Model-implied relationship between inattentive symptom counts (top) and groups (bottom) with the number of cigarettes currently smoked per day.

for both White ($b = -0.5$, $p = .02$) and Black ($b = -1.5$, $p = .0014$) women, and this effect was more pronounced among Black than White women. When ADHD was represented categorically, the effect of race was slightly changed ($b = 2.86$, $p < .0001$). There also was now a trend for women in higher income households to report a later age at first smoking ($b = 0.26$, $p = .08$). However, we found no indication that women with ADHD subtypes differed relative to the nonsymptomatic group with respect to age at first smoking (including no evidence for race by symptom group interactions).

Discussion

The goals of the present study were to investigate the relationships between retrospectively recalled childhood ADHD and smoking-related outcomes for a large sample of new mothers. Although retrospective ADHD symptomatology was not predictive of having smoked during pregnancy or being a current smoker, it was predictive of the number of cigarettes smoked per day both during pregnancy and currently, as well as the age at onset of smoking. These effects held up in the presence of a well-established set of demographic factors (age, race, and household income) that were related to smoking behaviors, as well as current reports of mental health functioning that could

Figure 3. Race $\times$ inattentive symptom count $\times$ hyperactive-impulsive (HyperImp) symptom count interaction in prediction of the age at first cigarette smoking.

have biased the recall of childhood ADHD symptomatology or recall of smoking behavior.

In contrast to previous studies, which reported linear associations between retrospectively reported ADHD symptoms and smoking outcomes, the present study reported nonlinear associations. Specifically, among women who smoked during pregnancy, those who retrospectively endorsed 2–5 hyperactive-impulsive symptoms during childhood reported smoking 2–8.5 more cigarettes per day during their pregnancy relative to women who endorsed 0–1 or 6–9 symptoms. This effect held even after accounting for inattentive symptoms, demographic factors, and control variables. Among women who were currently daily smokers, those who endorsed 2–7 inattentive symptoms during childhood reported smoking 3–9 more cigarettes per day currently, relative to women who endorsed 0–1 or 8–9 inattentive symptoms. This effect held even after accounting for retrospectively reported hyperactive-impulsive symptoms, demographic factors, and control variables. Consistent with these nonlinear effects, categorical variables designating ADHD diagnostic cutoffs were never significant predictors of either the propensity to smoke or the frequency of smoking currently or during pregnancy.

Among daily smokers, we found evidence that retrospectively reported ADHD symptoms were associated with earlier age at smoking onset. Specifically, greater inattentive symptoms were associated with earlier age at smoking onset; however, this effect held only when hyperactive-impulsive symptoms were low. The magnitude of this effect was stronger for Blacks than Whites. These findings are consistent with our previous study in which we reported that the highest level of self-reported ADHD symptoms was associated with an age at onset of regular smoking 1.3 years earlier than those reporting the lowest levels of symptoms (Kollins et al., 2005). Also, in studies of clinical samples, ADHD diagnosis has been shown to be associated with earlier age at smoking onset (e.g., 13.9 years for ADHD vs. 15.3

years for non-ADHD controls; Molina & Pelham, 2003). In contrast to symptom counts, we found no indication that categorical variables designating ADHD subtypes predicted age at onset.

Given the paucity of research with exclusively female samples, we adopted an exploratory approach to determining the nature of the relationship between ADHD symptoms and smoking outcomes. Few studies have noted whether nonlinear relationships between ADHD and smoking behaviors were tested. Hence, rather than being an anomaly, the current results may be among the first to reveal a relationship that existed but was not evaluated in previous studies. In our previous work, we reported a trend for a nonlinear effect ($p = .07$) for the relationship between inattentive symptoms and lifetime risk of regular smoking (Kollins et al., 2005). Given the large sample size of that study, this trend was not pursued. However, given that participant sex was treated as a confounder variable in that study, the effect might have been significant had it been tested separately for males and females. Taken together, these results suggest that future studies would benefit from explicitly testing and reporting linear, nonlinear, and multiplicative (inattentive $\times$ hyperactive-impulsive) relationships between ADHD and smoking outcomes in both sexes.

The self-medication hypothesis has been advanced as an explanation for the association between ADHD and smoking (Khantzian, 1997; Wilens, 2002). The notion is that nicotine ameliorates some of the behavioral and cognitive difficulties associated with ADHD; hence, adolescents and adults with ADHD may smoke to reduce their symptoms. The results reported here are consistent with the notion of self-medication but qualify it by suggesting that this holds only for women experiencing intermediate levels of ADHD symptomatology during childhood (i.e., those endorsing 2–7 inattentive or 2–5 hyperactive-impulsive symptoms). This may be true if one assumes that women who experience the highest levels of ADHD symptomatology actively seek more formal treatment (e.g., medication) for their ADHD in adulthood. Unfortunately, information on mental health treatment in this sample was not available for us to test this speculation. An alternative explanation is that adult women who report the highest levels of childhood ADHD symptoms may not have been adequately represented in the present sample (i.e., were less likely to be new mothers or to have agreed to participate in the study).

ADHD is among the most heritable of all psychiatric disorders, with most studies suggesting heritability estimates of 60%–80% (Faraone & Khan, 2006). In addition, prenatal maternal smoking is a well-established significant risk factor for the development of ADHD and other disruptive behaviors (Langley, Rice, van den Bree, & Thapar, 2005). Since mothers who are genetically predisposed for ADHD also are more likely to smoke and to have more difficulty quitting during pregnancy (Pomerleau et al., 1995), risk for ADHD and related behavioral problems in their offspring is likely to be greatly increased. The present findings suggest that more aggressive efforts to target women smokers with even moderate levels of ADHD symptomatology may be prudent to mitigate at least a portion of this risk.

The present study had a number of strengths. It is the first study to focus exclusively on the relationship between ADHD and smoking outcomes among new mothers. Moreover, it benefited from representation of both Black and White participants. With regard to limitations, the sampling plan was designed to yield a representative sample of children who were born to fam-

ilies residing in communities characterized by two distinct forms of poverty—not a representative sample of all women, of all women of childbearing age, or of all women who smoked. Hence, generalization is limited to women who recently gave birth to a child. Second, the study is based on a cross-sectional design and relied on retrospective reports. Although the reported rates of ADHD symptoms were consistent with other studies using similar methodology, no external checks of symptom validity were available. Similarly, the frequency of smoking during pregnancy was based on retrospective reports of behaviors 2–3 years previously and may have been biased by a number of factors (e.g., current smoking behavior and social desirability).

The present study adds to a growing literature documenting an association between ADHD symptoms experienced in childhood and adolescence and subsequent risks for smoking. It will be important for future research to continue to use community-based samples to understand these relationships, as well as to establish an agreed-upon taxonomy for defining the full range of smoking outcomes, including definitions for lifetime smoking, daily smoking, smoking during pregnancy, age at onset of smoking (experimentation vs. regular use), dosage of cigarette (and other tobacco products) use, as well as progression to states of nicotine dependence. The present results also suggest that future studies should consider both linear and nonlinear relationships between ADHD and smoking outcomes and consider whether these patterns are moderated by sex, race, or both. Finally, these results suggest that children who are born to women who have a childhood history of even intermediate levels of ADHD symptomatology may be at increased risk for compromised health outcomes by virtue of their exposure to increased levels of cigarette smoking during both prenatal and postnatal development.

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Declaration of Interests

None declared.

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