

Association Between Smoking and Attention-Deficit/Hyperactivity Disorder Symptoms in a Population-Based Sample of Young Adults

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Context: Attention-deficit/hyperactivity disorder (ADHD) has been associated with increased risk of smoking, and some studies have suggested that inattentive symptoms specifically may underlie this risk. Few studies, however, have examined ADHD symptoms in nonclinical samples to determine the extent to which the number of symptoms—independent of the full diagnosis—confer risk for smoking-related outcomes.

Objective: To evaluate the relation between smoking-related variables and the number of retrospectively reported ADHD inattentive and hyperactive/impulsive symptoms in a population-based sample of young adults.

Design, Setting, and Participants: The study population consists of 15 197 eligible participants from wave III of the National Longitudinal Study of Adolescent Health, a nationally representative sample of adolescents followed from 1995 to 2002.

Main Outcome Measures: Logistic regression was used to examine the relation between self-reported ADHD symptoms and the lifetime likelihood of being a regular smoker, defined by having smoked at least 1 cigarette a day for 30 days. For individuals reporting regular smok-

ing, we also examined the extent to which ADHD symptoms predicted age at onset of regular smoking and number of cigarettes smoked.

Results: A linear relation was identified between the number of self-reported inattentive and hyperactive/impulsive symptoms and smoking outcome measures ($P < .001$ for each symptom domain). Controlling for demographic and conduct disorder symptoms, each reported inattention and hyperactivity/impulsivity symptom significantly increased the likelihood of ever regular smoking (odds ratio [OR], 1.11; 95% confidence interval [CI], 1.08-1.14 and OR, 1.16; 95% CI, 1.13-1.19, respectively). For those reporting lifetime regular smoking, reported symptoms decreased the estimated age at onset and increased the number of cigarettes smoked.

Conclusions: Self-reported ADHD symptoms were found to be associated with adult smoking outcome variables in this nationally representative sample, providing further evidence of a likely link between ADHD symptoms and risk for tobacco use.

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CLINICAL SAMPLES OF INDIVIDUALS with attention-deficit/hyperactivity disorder (ADHD) smoke at rates significantly higher than the general population and/or non-diagnosed controls among both adults (41%-42% vs 26% for ADHD and non-ADHD, respectively)^{1,2} and adolescents (19%-46% vs 10%-24% for ADHD and non-ADHD, respectively).²⁻⁶ Moreover, these studies have shown that individuals with ADHD report earlier initiation of smoking than their nondiagnosed peers and are more likely to progress from initiation to regular smoking.⁴⁻⁶ Adult smokers with ADHD also report more difficulty quitting than individuals in the general population.¹

A number of studies have reported that the co-occurrence of ADHD and substance use disorders in general can be accounted for almost completely by the presence of comorbid conduct disorder (CD).⁷⁻⁹ Attention-deficit/hyperactivity disorder, however, has been shown to be an independent risk factor for tobacco use specifically in clinical and high-risk samples, even after controlling for comorbid CD.^{3,5} Moreover, there is some evidence that specific problems with inattention and related deficits in executive functioning significantly predict smoking, even after controlling for conduct problems.^{5,10,11} Further, the risk for smoking has been shown to be more strongly associated with the number of reported inattentive (IN) symptoms than by the diagnosis of ADHD itself.¹¹

The relationship between smoking and inattention is also supported by studies using non-ADHD samples. In a group of smokers enrolled in a smoking cessation program, ADHD-IN symptoms were significantly associated with smoking motivation factors including smoking for stimulation.¹² Data from a large community sample of adolescents also showed that problems with attention differentially predicted smoking status.¹³

To date, studies examining the relationship between ADHD symptoms and smoking have focused primarily on clinical or high-risk samples. Data from several larger community samples as well as laboratory studies in humans and nonhumans have also suggested that nicotine self-administration (ie, smoking) may be related to its augmenting effects on attention and executive functioning.^{14,15} Given the demonstrated association between inattention and smoking across diverse samples and in-laboratory experiments, the objective of the present study was to examine the link between self-reported ADHD symptoms and smoking status in a large population-based sample of young adults while controlling for the confounding effects of CD symptoms, sex, indicators of socioeconomic status (parental education and receipt of public assistance), and ethnicity. We examined data from the National Longitudinal Study of Adolescent Health (Add Health) to accomplish this goal.^{16,17}

METHODS

DATA SOURCE

The study population was drawn from 20 747 adolescents from Add Health, a nationally representative study of adolescents. The longitudinal cohort includes 15 197 eligible respondents who participated in in-home surveys on 3 separate occasions (April to December, 1995; April to August, 1996; and August 2001 to August 2002). The mean (SD) age of survey participants on the 3 waves of data collection was 15.65 (1.75) years, 16.22 (1.64) years, and 22.96 (1.77) years. By design, the Add Health survey included a sample stratified by region, urbanicity, school type, ethnic mix, and size to garner a nationally representative sample. Precise details regarding the design and data collection have been described elsewhere.^{16,17}

SAMPLE

For the present study, poststratification weights were unavailable for 875 participants and the subpopulation of women who were pregnant (n=379) were further excluded because it was believed that women who were pregnant may alter their smoking behaviors. Information regarding CD symptoms and ADHD symptoms was collected during waves I and III, respectively. The final analysis sample included 13 852 adolescents (49.5% male, 50.5% female; 62.9% white, 37.1% nonwhite) with complete data on items assessing ADHD and tobacco use.

MEASURES

Participants were separated into 2 groups based on their self-reported smoking status during wave III. Those reporting having ever smoked at least 1 cigarette every day for 30 days were classified as "ever-regular smokers" (n=5344, 38.6%). All other individuals were classified as "never-regular smokers" (n=8506, 61.4%). The never-regular smoker group was composed of individuals who had never tried smoking, had only taken 1 or 2

puffs, who had taken puffs but never smoked an entire cigarette, or who had smoked an entire cigarette but never smoked regularly. We chose this classification since the primary aim of the study was to determine whether ADHD symptoms increased the lifetime risk for regular smoking, regardless of current smoking status. Smoking behavior has been assessed in a similar manner in other epidemiological studies and has been shown to have acceptable reliability and validity among children and adolescents.^{13,18-20}

To further assess the relation between ADHD symptoms and smoking behaviors, 2 additional variables were examined: (1) self-reported age at onset of regular smoking (5-26 years); and for current regular smokers, (2) the number of cigarettes smoked per day in the last 30 days (1-100 cigarettes).

In wave III, participants were asked to retrospectively report ADHD symptoms experienced between the ages of 5 and 12 years. Respondents were asked to report the frequency of a symptom using a 4-point Likert scale: never or rarely, sometimes, often, very often. One item asked in the retrospective ADHD section of wave III ("You were spiteful or vindictive") is not a DSM-IV ADHD symptom and was excluded from analyses; while 1 DSM-IV impulsivity symptom ("Often interrupts or intrudes on others") was not included in the retrospective ADHD section. Thus, our analyses included responses to 9 IN and 8 hyperactive/impulsive (HI) symptoms.

A symptom was considered present if it was experienced "often" or "very often." This approach to dichotomizing symptoms has been used in other community-based studies of ADHD symptomatology and is considered clinical convention.²¹ For our primary analyses, the total number of symptoms reported (0-9 for IN; 0-8 for HI) was used as a measure of ADHD severity to assess the relation between symptoms and both smoking status and other smoking outcomes (eg, age at onset of regular smoking, number of cigarettes smoked per day). For descriptive and bivariate analyses, individuals were classified into 1 of 4 groups based on the number of reported symptoms: (1) 6 or more IN symptoms, fewer than 6 HI symptoms; (2) 6 or more HI symptoms, fewer than 6 IN symptoms; (3) 6 or more IN symptoms and 6 or more HI symptoms; and (4) fewer than 6 HI and fewer than 6 IN symptoms. The 6-symptom cutoff was chosen to be consistent with DSM-IV ADHD criteria requiring the presence of 6 or more symptoms from either the IN or HI symptom domains.

Internal consistency of the ADHD items specifically from the Add Health data set was found to be adequate (Cronbach $\alpha = .86$). Moreover, parents of individuals reporting 6 or more symptoms on either or both IN and HI scales were more likely to indicate learning or other behavioral problems at wave I; and these individuals were also more likely to report taking medication for ADHD at wave III ($\chi^2 = 7.96 - 99.83$; $P = .005 - .001$).

Since CD has been shown in previous studies to be an important mediator of the risk between ADHD and substance use,²² we included a measure of CD symptoms in multivariate analyses. This variable consisted of responses to 13 questions that corresponded to DSM-IV symptom criteria for CD that have been used in previous studies with the Add Health database to characterize CD²³ and was shown in our analysis to have adequate internal consistency (Cronbach $\alpha = .67$).

Factors related to socioeconomic status have also been shown to be associated with the development of smoking²⁴ and thus, we controlled for parental report of the highest education level of either themselves or their spouse and whether the family of the participant was receiving public assistance at wave I.

STATISTICAL ANALYSIS

Statistical analyses were conducted using SAS-callable SUDAAN (version 8.0) statistical software (Research Triangle Institute, Research Triangle Park, NC).²⁵ The SUDAAN software allows

Table 1. Baseline Sex, Ethnicity, ADHD Symptom, and CD Symptom Characteristics of Ever and Never Regular Smokers

| | Regular Smoking, No. (%) | | χ^2 | P Value |
|-----------------------------|--------------------------|--------------|------------------|-----------|
| | Never | Ever | | |
| Sex | | | | |
| Male | 4237 (61.78) | 2621 (38.22) | $\chi^2 = 0.19$ | .67 |
| Female | 4269 (61.06) | 2723 (38.94) | | |
| Ethnicity | | | | |
| White | 4677 (53.72) | 4030 (46.28) | $\chi^2 = 92.6$ | <.001 |
| Nonwhite | 3830 (74.46) | 1314 (25.54) | | |
| ADHD symptoms | | | | |
| <6 HI and <6 IN | 8046 (62.81) | 4764 (37.19) | $\chi^2 = 82.43$ | <.001 |
| ≥ 6 IN and <6 HI | 176 (50.43) | 173 (49.57) | | |
| ≥ 6 HI and <6 IN | 162 (41.54) | 228 (58.46) | | |
| ≥ 6 HI and ≥ 6 IN | 123 (40.73) | 179 (59.27) | | |
| CD symptoms | Mean (SE) | Mean (SE) | OR | 95% CI |
| | 0.70 (0.01) | 1.27 (0.02) | 1.35 | 1.29-1.43 |

Abbreviations: ADHD, attention-deficit/hyperactivity disorder; CD, conduct disorder; CI, confidence interval; HI, hyperactive/impulsive; IN, inattentive; OR, odds ratio.

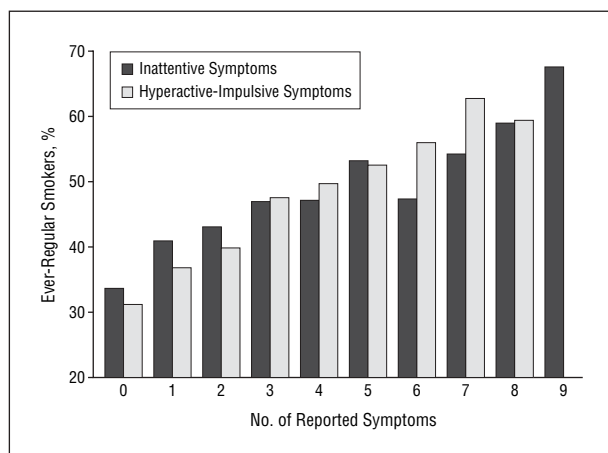


Figure 1. Percentage of individuals with attention-deficit/hyperactivity disorder inattentive and hyperactive-impulsive symptoms reporting ever regular smoking.

for control of survey design effects of individuals clustered in sampling units of school and stratification of geographic region. Poststratification weights were applied to allow the results to be comparable to young adults in the United States population. Initial bivariate analyses were conducted to examine the relationship between risk factors and smoking status. This was followed by a multiple logistic regression analysis in which the relationship between ADHD and smoking was examined with other risk factors in the model.

RESULTS

SAMPLE CHARACTERISTICS

The weighted percentages of respondents reporting 6 or more IN symptoms (2.71%), 6 or more HI symptoms (2.95%), or 6 or more of both IN and HI symptoms (2.51%) are consistent with other known prevalence es-

Table 2. Odds Ratios and 95% CIs for Risk of Ever Regular Smoking by IN and HI ADHD Symptoms

| No. of Self-reported Symptoms | OR | 95% CI | |
|-------------------------------|------|-------------|-------------|
| | | Lower Limit | Upper Limit |
| Inattentive | | | |
| Overall | 1.14 | 1.11 | 1.17 |
| 1 | 1.36 | 1.21 | 1.53 |
| 2 | 1.43 | 1.21 | 1.69 |
| 3 | 1.68 | 1.39 | 2.04 |
| 4 | 1.67 | 1.26 | 2.19 |
| 5 | 2.26 | 1.71 | 2.99 |
| 6 | 1.94 | 1.4 | 2.7 |
| 7 | 2.22 | 1.45 | 3.39 |
| 8 | 2.67 | 1.59 | 4.47 |
| 9 | 3.93 | 2.35 | 6.56 |
| Hyperactive/impulsive | | | |
| Overall | 1.2 | 1.17 | 1.23 |
| 1 | 1.27 | 1.12 | 1.43 |
| 2 | 1.38 | 1.19 | 1.6 |
| 3 | 2.03 | 1.72 | 2.4 |
| 4 | 2.18 | 1.81 | 2.63 |
| 5 | 2.28 | 1.79 | 2.89 |
| 6 | 2.95 | 2.23 | 3.89 |
| 7 | 3.86 | 2.69 | 5.55 |
| 8 | 2.92 | 1.75 | 4.87 |

Abbreviations: ADHD, attention-deficit/hyperactivity disorder; CI, confidence interval; HI, hyperactive/impulsive; IN, inattentive; OR, odds ratio.

timates for ADHD in the general population and in previous studies of ADHD symptoms and smoking.^{13,26,27} Similarly, the reported rates of lifetime regular smoking (42.57%)¹ are consistent with prevalence data from other sources.²⁸ Mean (SE) age of the respondents at wave III of data collection was 21.94 (0.02). Mean (SE) number of CD symptoms reported from wave I was 0.90 (0.01). With regard to factors related to socioeconomic status, 11.3% parents had less than a high school degree, 26.7% had completed high school or an equivalent degree, 30.5% had completed an associates degree or some college, 31.6% had completed college or higher, and 8.9% of families were recipients of public assistance at wave I.

BIVARIATE ANALYSES

Reporting higher numbers of CD symptoms, being Caucasian, and reporting 6 or more IN and/or HI symptoms were all significantly associated with higher likelihood of ever regular smoking (**Table 1**). Since one of the primary aims of the present study was to examine the incremental contribution of ADHD symptoms, even at levels below traditional clinical thresholds, we analyzed the rates of ever regular smoking as a function of total number of retrospectively reported symptoms. There was a strong relationship between the number of symptoms and smoking status for both IN and HI symptom domains (**Figure 1**).

The odds ratios (ORs) for self-reported ADHD symptoms as predictors of ever regular smoking were significant (**Table 2**). Overall, each additional symptom reported increased the odds of being an ever regular smoker by 14% and 20% for IN and HI symptoms, respectively.

Table 3. Odds Ratios and 95% CI for Logistic Regression Models Predicting Ever Regular Smoking

| Model | OR (95% CI) | |
|----------|------------------|-----------------------|
| | Inattentive | Hyperactive-Impulsive |
| Model 1* | 1.14 (1.11-1.17) | 1.20 (1.17-1.23) |
| Model 2† | 1.14 (1.11-1.17) | 1.19 (1.16-1.22) |
| Model 3‡ | 1.11 (1.08-1.14) | 1.16 (1.13-1.19) |
| Model 4§ | 1.02 (0.98-1.06) | 1.15 (1.11-1.19) |

Abbreviations: CI, confidence interval; OR, odds ratio.

*Unadjusted model.

†Adjusted for age, race, socioeconomic status, and sex.

‡Adjusted for age, race, socioeconomic status, sex, and conduct disorder.

§Adjusted for age, race, sex, socioeconomic status, conduct disorder, and other attention-deficit/hyperactivity disorder symptom domain.

A test of trend for each symptom indicated a significant linear trend ($P < .001$ for both HI and IN). A test for a quadratic trend was also examined and found not to be significant ($P = .12$ for hyperactivity and $P = .07$ for inattention). Thus, the changes in individual ORs for each additional reported symptom were generally positive and linear for both symptom domains.

MULTIPLE LOGISTIC REGRESSION

Relations between the number of self-reported ADHD symptoms and ever regular smoking after controlling for other potentially important predictor variables were examined using multiple logistic regression. The addition of demographic variables (**Table 3**) (age, race, sex, and parental education, receipt of public assistance [model 2]) and CD symptoms (model 3) resulted in decreased ORs for both HI (OR, 1.16; 95% CI, 1.13-1.19) and IN symptoms (OR, 1.11; 95% CI, 1.08-1.14), though both remained significant. In model 4, both symptom domains were included, which again decreased the OR for both domains although to a substantially larger extent for IN (OR, 1.02; 95% CI, 0.98-1.06) compared with HI (OR, 1.15; 95% CI, 1.11-1.19). Consistent with these ORs, comparisons of log likelihood ratios indicated greater improvement in fit by adding HI to a model already including IN ($\chi^2 [1] = 99.30$, $P < .001$) than by adding IN to a model already including HI ($\chi^2 [1] = 2.14$, $P = .17$).

To assess ORs for more clinically relevant variables, the same models mentioned earlier were calculated using symptom cutoff variables as predictors. After accounting for all other variables (including the other symptom category), the odds of becoming a lifetime regular smoker were 1.23 and 2.13 times greater than for those individuals with 6 or more IN and HI symptoms, respectively. Individuals reporting 6 or more IN and 6 or more HI symptoms were 2.28 times more likely to become regular smokers.

IMPACT OF SELF-REPORTED ADHD SYMPTOMS ON OTHER SMOKING OUTCOMES

To further explore the association between retrospectively reported ADHD symptoms and smoking status, we conducted 2 additional analyses of regular smokers. In-

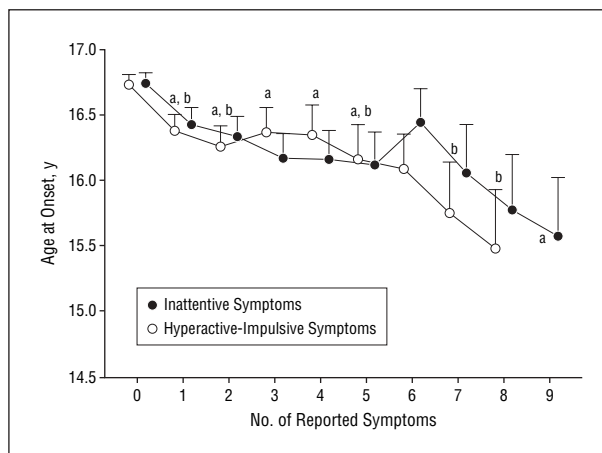


Figure 2. Estimated age at onset of regular smoking among individuals with a lifetime history of regular smoking as a function of reported number of attention-deficit/hyperactivity disorder inattentive and hyperactive-impulsive symptoms. Letters indicate points significantly different from 0 reported symptoms for inattentive symptoms (a) and hyperactive-impulsive symptoms (b).

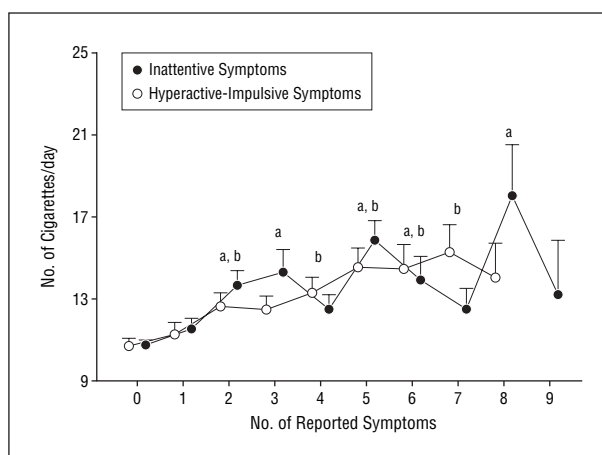


Figure 3. Estimated number of cigarettes smoked per day in the last month among current regular smokers as a function of the reported number of attention-deficit/hyperactivity disorder inattentive and hyperactive-impulsive symptoms. Letter designations are identical to Figure 2.

attention and HI symptoms were both significantly associated with age at onset of regular smoking ($\beta = -0.12$, $SE = 0.02$, $P < .001$; and $\beta = -0.11$, $SE = 0.02$, $P < .001$, respectively). Among lifetime regular smokers, the estimated age at onset of regular smoking was 16.67 and 16.73 years in individuals reporting zero IN and HI symptoms, respectively (**Figure 2**). By contrast, individuals reporting the highest number of symptoms for the IN and HI symptom domains began smoking at ages 15.44 and 15.48 years, respectively.

Further, among current regular smokers, the number of self-reported IN and HI ADHD symptoms were positively associated with the number of cigarettes smoked per day in the past 30 days, ($\beta = 0.64$, $SE = 0.11$, $P < .001$; and $\beta = 0.63$, $SE = 0.11$, $P < .001$, respectively) (**Figure 3**). Regular smokers with 0 IN and HI symptoms smoked an estimated 10.71 and 10.62 cigarettes per day while smokers reporting the highest number of symptoms possible smoked 13.18 and 13.97 cigarettes per day, respectively.

In the present analyses, we observed significant relations between the number of reported retrospective ADHD symptoms and lifetime regular cigarette smoking in a sample of young adults, controlling for demographic variables and CD symptoms. These relations among ADHD symptoms and smoking behavior were largely linear with each additional symptom typically conferring additional risk of regular smoking. Hyperactivity/impulsivity symptoms were found to be a better predictor of lifetime regular smoking than IN symptoms. Among regular smokers, more ADHD symptoms were also associated with earlier regular smoking and with greater cigarette consumption—again in a largely linear manner. The present findings are consistent with previous reports linking ADHD symptoms to smoking.^{5,10,11,13} However, contrary to previous studies which have reported a stronger link between IN symptoms and smoking, our data suggest that HI symptoms confer greater risk for ever regular smoking. Several methodological features of our study may account for this difference. First, the average age of respondents in the present sample (21.94 years) was considerably higher than other studies (eg, 10th grade high school students¹³). Since the present sample was older, the opportunity to initiate and maintain smoking behaviors would necessarily be higher in this group. Moreover, the relation among ADHD symptoms and smoking might change over time. Future studies will be needed to examine this hypothesis.

Second, the primary smoking outcome measure in the current study was based on a history of lifetime regular use defined as smoking at least 1 cigarette per day for 30 days. In other studies, the primary smoking outcome variables were generally defined on the basis of much more infrequent use (eg, ever tried at least 1 puff of a cigarette¹³). As such, the use of a more stringent smoking outcome measure may have resulted in differential associations with HI and IN symptoms. The current study has several important strengths. First, the results reported here are based on a large epidemiological sample and were analyzed using population-based statistical approaches. As such, these findings extend those from community and clinical samples and are highly generalizable. A second strength is that the incremental influence of individual ADHD symptoms was examined while also controlling for the effects of other variables known to be associated with smoking (eg, socioeconomic status, CD symptoms). The results, therefore, allow for a more accurate view of the association among these important variables.

One limitation of the present study was the use of retrospectively reported ADHD symptoms as a primary independent variable. The nature of the Add Health survey was such that individuals were asked to report on symptoms occurring approximately 10 years before the time of report. The use of retrospective report is common in clinical practice when working with adults with ADHD and data exist that support the reliability and validity of these self-reports²⁹⁻³² (also J. N. Epstein, PhD, and S.H.K., unpublished data, 2005). We also demonstrated adequate reliability and validity of this approach

in the present sample. A second limitation of this study was that none of the models tested controlled for comorbid non-nicotine substance use disorders, which are also highly related to smoking. As such, it is possible that the relationship between ADHD symptoms and smoking could be confounded by concurrent substance use. Given the prevalence rates reported for smoking in our study however, this possibility seems unlikely.

The results of this investigation suggest that the number of HI symptoms are strongly associated with the likelihood of regular smoking, even in individuals reporting subclinical ADHD symptom levels. By contrast, IN symptoms are not significantly associated with lifetime regular smoking when all variables including HI symptoms are controlled. Thus, the findings extend existing research suggesting a possible link between ADHD symptoms and smoking risk. Further work is necessary, however, to more precisely characterize the nature of the relationship between ADHD symptoms and smoking. For example, it will be important in future studies to determine whether specific ADHD symptoms or symptom clusters are more strongly associated with smoking risk.

These findings also suggest that self-reported ADHD symptoms are associated with age at onset of regular smoking. Given the established link among earlier age at onset of smoking and risk for subsequent nicotine dependence and other drug use problems,³³⁻³⁵ these data are of high clinical and public health significance. The nature of the present study does not allow for any conclusions to be drawn regarding potential mechanisms that might account for the relation between ADHD symptoms and smoking. However, regulation of dopamine and serotonin have been linked with both smoking onset and dependence as well as with ADHD symptomatology.^{36,37} Subsequent experimental research will be needed to further examine the relationship between smoking and ADHD symptoms and possible underlying mechanisms. However, the robustness of the reported association emphasizes the need for subsequent experimental research to examine these relations.

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