Cigarette Smoking and ADHD: An Examination of Prognostically-Relevant Smoking Behaviors Among Adolescents and Young Adults

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Abstract

Introduction—Attention deficit/hyperactivity disorder (ADHD) is associated with health risks in adolescence which includes the potential for smoking cigarettes, early smoking initiation, and rapid progression to daily smoking. Much less is known, however, about prognostically-relevant smoking behaviors among individuals with childhood ADHD. Further research in this area is important for identifying individuals at pronounced risk for nicotine addiction, and for developing effective interventions for this population.

Method—This study examined initiation of cigarette smoking, progression to regular smoking, quantity of use, indicators of tobacco dependence, and quit rates among adolescents and young adults with (n=364) and without (n=240) childhood ADHD.

Results—Individuals with, versus without, ADHD histories were significantly more likely to become daily smokers independent of conduct disorder. They were also more likely to initiate smoking at younger ages and to progress to regular smoking more quickly. There were no significant group differences in cigarettes smoked per day, Fagerstrom Test of Nicotine Dependence or Nicotine Dependence Syndrome Scale scores or in smoking within 30 min of waking. However, smokers with ADHD reported more intense withdrawal and craving during periods of abstinence than nonADHD smokers. There were no significant group differences in number of quit attempts. Lastly, there were no significant differences among symptom persisters and desisters in daily smoking and amount.

Conclusions—Individuals with ADHD histories are at high risk for persistent smoking given their early onset, rapid course, and abstinence characteristics. Smoking cessation programs may need to be adapted or otherwise intensified for those with ADHD.

Keywords

ADHD; cigarette smoking; nicotine dependence; craving; withdrawal

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Cigarette smoking is the leading cause of preventable death in the United States, accounting for approximately one of every five deaths each year (Rostron, 2013). The prevalence of smoking among individuals with a comorbid psychiatric diagnosis is significantly higher than cigarette smoking in the general population (Aubin, Rollema, Svensson, & Winterer, 2012; Lasser et al., 2000), and approximately 21–31% of smokers also exhibit psychiatric symptoms (e.g. mood, anxiety, substance use) (Aubin et al., 2012).

Cigarette smoking figures prominently among the most common substance use behaviors of individuals with Attention-Deficit/Hyperactivity Disorder (ADHD) histories (Barkley et al, 1990; Burke, Loeber & Lahey, 2001; Charach, Yeung, Climans & Lillie, 2011; Derefinko & Pelham, 2014; Hartsough & Lambert, 1987; Milberger et al., 1997; Molina & Pelham, 2003; Sibley et al., 2014). ADHD is among the most prevalent mental health disorders of childhood and is estimated to occur in approximately 5–8% of children and 4–5% of adults (Kessler et al., 2006; Visser et al., 2014). ADHD is characterized by symptoms of inattention, impulsivity, and hyperactivity, as well as impairments in activities of daily living (e.g., academic and social functioning) in both childhood (Bagwell, Molina, Pelham, & Hoza, 2001; Biederman et al., 2004; DuPaul et al., 2001; Kent et al., 2011) and adulthood (Babinski et al., 2010; Biederman et al., 2006; Kessler et al., 2006; Murphy & Barkley, 1996; Sibley et al., 2012). Childhood ADHD increases risk for multiple adverse outcomes, including alcohol and other drug use, abuse, and dependence (August et al., 2006; Barkley et al., 1990; Charach, 2011; Derefinko & Pelham, 2014; Ernst et al., 2006; King, Iacono & McGue, 2004; Lambert & Hartsough, 1998; Lee, Humphreys, Flory, Liu, & Glass, 2011; Molina & Pelham, 2003; Molina et al., 2007). Children with ADHD are also more likely to become regular cigarette smokers. They initiate smoking at earlier ages (Kollins et al., 2005; Milberger et al., 1997; Molina & Pelham, 2003; Sibley et al., 2014) and are more likely to continue smoking and to progress to regular smoking by adolescence or adulthood (Lambert & Hartsough, 1998; Molina & Pelham, 2003; Molina et al., 2013; Rohde et al., 2004, Sibley et al., 2014).

Converging lines of research suggest that cognitive (i.e. attention, Levin et al., 1996; inhibition, Levin et al., 2001, Potter & Newhouse, 2004, 2008; Ashare, Falcone, & Lerman, 2014), affective (i.e. emotion regulation; Kassel, Stroud, & Paronis, 2003), neurobiological (dopaminergic systems) and genetic factors (Faraone et al., 2005; Munafo et al., 2004; McClernon et al., 2008) likely play key roles in the ADHD-smoking comorbidity (McClernon & Kollins, 2008 and Modesto-Lowe et al., 2010). Additionally, psychological and social factors such as personality (e.g. impulsivity; Doran et al., 2004; Mitchell, 1999; Reynolds et al., 2004), deviant peer associations, ineffective coping strategies, and parenting (Harakeh et al., 2004; Laucht et al., 2007; Marshal & Molina, 2006; Simons-Morton, et al., 2001) have been implicated in the ADHD-smoking relationship. Although the prospective studies demonstrating higher rates of smoking, earlier initiation, and faster progression among ADHD smokers (Milberger et al., 1997; Molina & Pelham, 2003; Rohde et al., 2004; Sibley et al., 2014) represent important initial efforts toward understanding the ADHD-smoking relationship, other important smoking characteristics (i.e. heaviness of smoking, dependence, withdrawal, quit attempts) have been under-studied. These behaviors are known in the smoking literature to be important for prognosis during adolescence/young adulthood. Also, existing studies have, for the most part, been retrospective in nature (c.f. McClernon et

al., 2008) and based on individuals with adult-diagnosed ADHD (Fuemmeler et al., 2007; Kollins et al., 2005; McClernon et al., 2008; Pomerleau et al., 2003).

Experimentation with smoking during adolescence is common and while most teen smokers do not progress to regular smoking, adolescent smoking is a risk factor for smoking in adulthood (Chassin, Presson, Sherman, & Edwards, 1990; Chassin, Presson, Rose & Sherman, 1996). Most adult daily smokers begin smoking during adolescence (U.S. Department of Health and Human Services, 2014). Initiation to smoking in adolescence is associated with a longer lifetime duration of smoking, heavier smoking rates, nicotine dependence and difficulty quitting (Breslau & Peterson, 1996; Hymowitz et al., 1997; Khuder, Dayal, & Mutgi, 1999). Adolescence and young adulthood are developmentally important periods for researching the initiation and progression of smoking behaviors. Thus, additional research is needed on initiation and rapidity of progression to daily smoking among young people with ADHD.

Factors that maintain smoking over time are prognostically-relevant because of their association with quitting and abstinence. Nicotine dependence (defined as chronic and repetitive use of nicotine products, tolerance for nicotine, experiencing withdrawal symptoms after abstaining, and difficulty quitting despite knowledge of the harmful health consequences of smoking (APA, 2013)), and quantity of cigarette consumption are relatively independent (Donny, Griffin, Shiffman & Sayette, 2008). Although the majority of daily smokers consume cigarettes at high rates each day (Shiffman, 1989), not all daily smokers are nicotine dependent (Donny & Dierker, 2007; Shiffman, Kassel, Paty, Gnys, & Zettler-Segal, 1994; Shiffman, Paty, Gnys, Kassel, & Elash, 1995). However, beginning in adolescence, each are prognostic of smoking behavior later in life (Breslau & Peterson, 1996; Chen & Kandel, 1995; Colby, Tiffany, Shiffman, & Niaura, 2000; Prokhorov et al., 2001; Sargent, Mott, & Stevens, 1998). The studies of dependence and quantity in relation to ADHD have largely focused on adult smokers cross-sectionally; findings are mixed, with some suggesting that adult ADHD is related to higher quantities (Kollins et al., 2005) and dependence (Fuemmeler et al., 2007), and others suggesting no difference (McClernon et al., 2008; Pomerleau et al., 2003). More research is needed to better understand the role these smoking maintenance factors play in the ADHD-smoking association and especially in young samples studied prospectively from ADHD in childhood.

Withdrawal symptom severity is a specific maintenance factor that may begin in adolescence (Colby, Tiffany, Shiffman, & Niaura, 2000) and is prognostic of future smoking behavior (Piasecki, 2006; Prokhorov et al., 2001). When smokers abstain, they typically experience a range of affective (e.g. irritability) and cognitive (e.g. difficulty concentrating) symptoms, and more severe withdrawal symptoms predict a faster return to smoking (Ferguson, Shiffman & Gwaltney, 2006; Piasecki at al., 2003a; 2003b; Javitz, Lerman, & Swan, 2012). Among adolescent smokers, craving (a strong desire to smoke) is the most commonly reported withdrawal symptom (Colby, Shiffman, Tiffany, & Niaura, 2000). There is preliminary evidence, based on retrospective recall, that adult smokers with ADHD experience more severe self-report and laboratory-based withdrawal symptoms than adult smokers without ADHD (McClernon et al., 2008; McClernon et al., 2011; Pomerleau et al., 2003). It has been posited that individuals with ADHD may smoke to alleviate their

symptoms of ADHD (i.e. "self-medication" hypothesis) (e.g. Evans & Drobes, 2008; Gehricke et al., 2007) and there is a growing, albeit small, literature suggesting that smoking is negatively reinforcing by reducing ADHD symptoms, primarily inattention symptoms (Levin et al., 1996; Wilens et al., 1999). Either way, these findings suggest that during periods of abstinence, smokers with ADHD experience more withdrawal symptoms, particularly inattention, resulting in an increased vulnerability to smoking maintenance. This hypothesis has not been tested for adolescents. Given that a) withdrawal and craving may appear during adolescence and are predictive of cessation, and b) individuals with ADHD may exhibit more severe symptoms, more research is needed to better understand symptom severity among ADHD smokers during adolescence and young adulthood.

Finally, attempts to quit smoking in the general population of adult smokers are frequent (CDC, 2014), often unplanned (Larabie, 2005) and correlate with eventual long-term abstinence (Hymowitz et al., 1997). In adolescence, it is typical for smokers to alternate between periods of smoking and abstinence. While a small fraction of adolescent smokers achieve successful cessation (Burt & Peterson, 1998), length of previous quit attempts (i.e. longer duration) during adolescence predicts successful cessation (Zhu et al., 2009). Individuals with ADHD may be less likely to make serious, sustained quit attempts because of their longer smoking histories (and other vulnerabilities). To our knowledge, there is no research comparing quit rates and abstinence duration between individuals with and without childhood histories of ADHD.

The present study aimed to expand the characterization of these prognostic smoking behaviors in a sample of individuals with ADHD who were diagnosed in childhood and interviewed later as adolescents or young adults. The Pittsburgh ADHD Longitudinal Study (PALS) provides the opportunity to examine prognostically-relevant smoking behaviors. We hypothesized that individuals with ADHD, compared to demographically similar individuals without ADHD histories, would report a) higher quantities of consumption and stronger dependence, b) more severe withdrawal symptoms including craving, and c) a lower frequency and duration of quit attempts. In addition, we expected to replicate group differences in attainment of smoking milestones, including more experimental and daily smoking at younger ages, and more rapid progression to regular smoking, in the ADHD compared to the nonADHD group, as well as extend the examination of the contribution of ADHD symptom persistence to current smoking (Molina & Pelham, 2014). A more clear understanding of tobacco use among individuals with ADHD during this critical developmental window may lead to improved understanding of smoking risk for people with ADHD and, ultimately, more targeted and effective prevention and treatment strategies.

Methods

Participants

ADHD Probands—Screening and diagnostic procedures have been described previously (Molina et al., 2012; Pedersen et al., 2014; Sibley et al., 2012). Briefly, participants with childhood ADHD were diagnosed with DSM-III-R or DSM-IV ADHD at the ADD Clinic, Western Psychiatric Institute and Clinic, in Pittsburgh, PA between 1987 and 1996. The average age at initial evaluation was 9.40 years (SD = 2.27 years). Ninety percent of children

were diagnosed between ages 5 and 12 years. ADHD probands were selected for follow-up interviews due to their diagnosis of ADHD and participation in a summer treatment program (STP) for children with ADHD (Pelham & Hoza, 1996). Diagnostic information was collected in childhood using standardized parent and teacher DSM-III-R and DSM-IV symptom rating scales (DBD; Pelham, Evans, Gnagy, & Greenslade, 1992) and a standardized semi-structured diagnostic interview administered to parents by a Ph.D. level clinician. Following DSM guidelines, diagnoses of ADHD were made if a sufficient number of symptoms were endorsed to result in diagnosis. Exclusion criteria for follow-up were assessed in childhood and included a full-scale IQ < 80, a history of seizures or other neurological problems, and/or a history of pervasive developmental disorder, schizophrenia, or other psychotic or organic mental disorders.

Of those eligible for follow-up in the PALS sample (n = 516), 70.5% (n = 364) participated for an average of M = 8.35 years after childhood diagnosis (S.D. = 2.79). A minority could not be located (n = 23); 129 refused or failed to participate. Participants were different ($p < .05$) from nonparticipants on only one (conduct disorder symptom ratings: participants $M = .43$, non-participants $M = .53$, Cohen's $d = .30$) of 14 comparisons on demographic (e.g. age at first treatment, race, parental education level, and marital status) and diagnostic (e.g., parent and teacher ratings of ADHD symptoms) variables from childhood. In childhood, average DSM-III-R ADHD symptom rating was 2.26, S.D. = .45, on a scale of 0 to 3; average number of DSM-III-R ADHD symptoms endorsed by parent or teacher was 12.56, S.D. = 1.78; percent with DSM-III-R ODD was 47%; percent with DSMIII-R CD was 36%. At the first PALS follow-up interview, when data used in this report were collected and which occurred on a rolling basis between 1999 and 2003, mean age was 17.75 years, S.D. = 3.39 years, range = 11 to 28 (three subjects were 26–28 years old), 89.6% were male, and 18.4% were racial/ethnic minority.

NonADHD comparison group—Individuals without ADHD were recruited into the PALS at the same time as the probands' recruitment into the follow-up study. NonADHD comparison participants were recruited on a rolling basis to ensure demographic similarity to the probands and were matched to probands (age within one year, sex, race, highest parental education). They were recruited from the greater Pittsburgh area from several sources including pediatric practices serving patients from diverse socioeconomic backgrounds, advertisements in local newspapers and the university hospital staff newsletter, local universities and colleges, and other miscellaneous sources. A telephone screening with parents gathered demographic characteristics, history of diagnosis and treatment for ADHD and other behavior problems, presence of exclusionary criteria as previously listed for ADHD probands, and a checklist of ADHD symptoms. Young adults (18+) also provided self-report. Individuals who met DSM-III-R criteria for ADHD were excluded. NonADHD comparison participants with subthreshold ADHD symptomatology, or with other psychiatric disorders other than those listed above as exclusionary, were retained. There were no statistically significant differences between the 364 ADHD probands and 240 nonADHD comparison participants on age, sex, ethnicity/racial minority status, or highest parental education. As with the ADHD probands, the nonADHD comparison participants were interviewed on an annual basis once recruited into the PALS.

Procedures

Interviews were conducted in the ADD Program offices by post-baccalaureate research staff. Data from the first follow-up interview of the children with ADHD, and the first interview of the nonADHD group, were used for this study. Informed consent was obtained and all participants were assured confidentiality of all disclosed material except in cases of impending danger or harm to self or others (reinforced with a DHHS Certificate of Confidentiality). In cases where distance prevented participant travel to WPIC, information was collected through a combination of mailed and telephone correspondence; home visits were offered as need dictated. Self-report questionnaires were completed either with pencil and paper or web-based versions.

Measures

Substance Use Questionnaire—Cigarette use was evaluated with a structured paper-and-pencil substance use questionnaire (SUQ) that is an adaptation of existing measures (e.g., Health Behavior Questionnaire, Jessor et al, 1989; National Household Survey of Drug Abuse, NHSDA 1992). The SUQ includes lifetime exposure questions (e.g., ever tried smoking; ever smoked a cigarette, more than just a puff; age started regular smoking; ever smoked on a daily basis), age of initiation, quantity of use, frequency of use, and number of quit attempts. Two items were added to assess craving ("If you had any craving, how severe was it, at its worst?") and difficulty concentrating ("If you had any difficulty concentrating, how severe was it at its worst?") during past periods of abstinence (i.e. "What is the longest period of time that you went without smoking after quitting or trying to quit?"). Participants rated their experience on a Likert scale of 1 (I had none) to 5 (Very Severe). Two-week test-retest reliability for the SUQ is good; for example, kappa for *ever tried* cigarettes = .87.

Fagerström Test for Nicotine Dependence (FTND)—The FTND is a widely used 6-item, self-report measure of nicotine dependence (Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991). The FTND has adequate psychometric properties (Pomerleau, Carton, Lutzke, Flessland, & Pomerleau, 1994). Using a sum score, the possible range of scores is from 0–10, with 5 indicating moderate nicotine dependence. Research has demonstrated predictive validity (for cessation) of a single dependence item from the FTND indicating whether a smoker has their first cigarette within 30 minutes of waking (e.g. Baker et al., 2007). As such, this item was also examined separately.

Nicotine Dependence Syndrome Scale (NDSS)—The NDSS (Shiffman, Waters, & Hickcox, 2004) is a five-factor (drive, priority, tolerance, continuity, and stereotypy), nineteen-item scale that requires participants to rate features of nicotine dependence (e.g. I feel a sense of control over my smoking) on a 5-point Likert scale (1 = Extremely Untrue, 5 = Extremely True). A total score and individual scale scores were calculated following recommended scoring procedures (see Appendix in Shiffman, Waters, & Hickcox, 2004). The NDSS was included as a second measure of nicotine dependence because of its multidimensional assessment of dependence. It exhibits adequate psychometric properties (Shiffman & Sayette, 2005; Shiffman, Waters, Hickcox, 2004) and demonstrates sensitivity to individual differences across the continuum of nicotine dependence (Shiffman & Sayette, 2005).

ADHD Symptom Persistence—ADHD symptom persistence, defined as 4 or more symptoms (Sibley et al., 2012) was obtained for ADHD probands from follow-up measures of symptoms reported by participants, parents and teachers at the follow-up interview.

Results

Cox Regressions were performed to compare *first trying* a cigarette, *first smoking* a cigarette *(more than a puff)*, and initiating *daily smoking* between the ADHD and nonADHD groups, as well as to compare the two groups on the time of progression to *daily smoking* from *first trying* a cigarette. Ordinal regression was used to examine group differences in cigarette consumption. ANOVAs were used to compare the two groups on dependence rates, withdrawal and craving, and quit attempts. Gender, childhood conduct disorder, race, and highest parental education were included as covariates in all analyses.

Before testing our hypotheses about ADHD and prognostically-relevant smoking behaviors, we first report smoking milestones and rates of initiation by ADHD/nonADHD group. For smoking milestones and for descriptive purposes, we report comparisons by age subgroups due to prior findings of age-specificity for other substance use (alcohol) outcomes (Molina et al., 2007). Binary logistic regressions were performed to compare smoking milestones among ADHD and nonADHD groups (see Table 1).

Smoking milestones

Table 1 displays percent of participants reaching smoking milestones (*ever tried a cigarette*, *ever smoked a cigarette (more than a puff)*, and *ever smoked on a daily basis*) by ADHD/ nonADHD group separately for each age subgroup. Individuals in the ADHD group were significantly more likely than those in the nonADHD group to have tried smoking, smoked more than a puff, and to have smoked daily in early and late adolescence. ADHD probands were also more likely to be daily smokers in the young adulthood groups.

Initiation of smoking behaviors

Compared to the nonADHD group, individuals in the ADHD group reported earlier onset of each milestone: *first trying* a cigarette (Wald statistic = 5.74, $df = 1$, $p = .02$, Hazard ratio = 1.35), *first smoking* a cigarette (Wald statistic = 2.76, $df = 1$, $p = .10$, Hazard ratio = 1.25), and *first daily smoking* (Wald statistic = 12.26, $df = 1$, $p < .001$, Hazard ratio = 2.02) (See Figure 1). The median ages for these behaviors (based on raw medians from participants who reported smoking) were as follows: ADHD probands *first tried* a cigarette on average at 13.00 years (SD = 3.20) vs. 14.00 years (SD = 2.56) for the nonADHD group, ADHD probands *first smoked* a cigarette on average at 14.00 years (SD = 3.00) vs. 15.00 years (SD = 2.29) for the nonADHD group, and ADHD probands *first began daily smoking* at 15.00 years (SD = 2.48) vs. 16.00 years (SD = 2.08) for the nonADHD group.

Speed of progression to daily smoking

Cox Regressions were performed on all participants who reported ever trying smoking to compare the two groups on the time of progression to *daily smoking* from *first trying* a cigarette (Figure 1). Compared to nonADHD participants, individuals with ADHD

progressed more rapidly (Wald statistic = 5.30, df = 1, p = .02, Hazard ratio = 1.57) from *first trying* smoking to *daily smoking*, having a 57% greater risk of progression each year. The probands' model-estimated median rate of progression from *first trying* a cigarette to *daily smoking* was one year, whereas the median rate of progression for nonADHD smokers was two years.

Cigarette consumption

Quantity of cigarette use was examined among individuals who reported currently smoking. This subsample included 128 in the ADHD group (Mean age = 19.4, SD = 2.8; 87% male; 87% Caucasian) and 39 in the nonADHD group (Mean age = 20.0, SD = 1.8; 82% male; 92% Caucasian). Based on the distributions, responses were grouped for analysis into fewer than 5 cigarettes per day (44 ADHD vs 16 nonADHD), between 5 and ½-pack per day (35 ADHD vs. 8 nonADHD), and about a pack or more per day (49 ADHD vs. 15 nonADHD). Using ordinal regression, these categories were regressed on ADHD group and years smoking (because the latter is known to predict higher quantity). Although years smoking (beta estimate = .18, Wald=11.9 (1), p = .001) predicted higher quantities of cigarette consumption, ADHD group (beta estimate = −.24, Wald=..35 (1), p > .05) did not.

Dependence

The NDSS and FTND total scores were compared between ADHD and nonADHD daily smokers (n=95 and 29, respectively) using an ANOVA controlling for total years smoking. The results in Table 2 show that there was no significant group difference in nicotine dependence scores, Fs <1, p's > .05, ds = .15, .18. Means of both scales indicate mild dependence in both groups (NDSS Range = −2.32 to .35; FTND Range = 0 to 9). Analyses of the NDSS subscale scores demonstrated that participants in the ADHD group did not significantly differ from participants without ADHD on any of the individual NDSS subscale scores, Fs < 1.17, p's > .28, ds < .40.

To examine differences in the time to first cigarette (within the day), responses were categorized into (1) less than 30 minutes after waking, and (2) more than 30 minutes after waking. There was a nonsignificant trend for the ADHD probands to be more likely to smoke within 30 minutes of waking (62%; n=65/105) compared to the nonADHD group (45%; n=14/31), X^2 = 2.81, p = .09. Given that the present sample includes adolescents whose smoking behaviors may be restricted due to environmental contexts (e.g. living with parents), an ordinal regression was performed to explore the effects of age. Neither age (beta estimate = .08, Wald statistic = .964, p > .05) nor the group (ADHD vs. nonADHD) × age interaction (beta estimate = .21, Wald statistic = .60, p >.05) predicted smoking within 30 minutes of waking.

Withdrawal (Difficulty Concentrating) & Craving

Smokers with ADHD reported significantly greater difficulty concentrating (F(1, 288) = 5.36, p=..02) and craving (F(1, 290) = 4.44, p = .04) during periods of abstinence compared to smokers in the nonADHD group (see Table 2 for descriptive statistics). Effect sizes were medium (see Table 2) with all participants indicating on average mild difficulty.

Quit Attempts

The number of reported quit attempts (see Table 2 for descriptive statistics) was compared between the ADHD (n = 99) and nonADHD (n = 34) groups after controlling for number of years smoking. No significant group differences emerged, F=1.55, p=.22. Additionally, the length (lower values reflect shorter duration of quit attempt) of serious quit attempts was compared between the ADHD and nonADHD groups after controlling for number of years smoking; no significant group differences were observed, F<1, p=.59. Effect sizes were small (see Table 2).

ADHD Symptom Persistence

Finally, we examined whether the persistence of ADHD symptoms was associated with likelihood of being a daily smoker and with current smoking amount (none, <5 cigarettes, ½ pack, 1 or more packs per day) among those with ADHD. For daily smoking, 73% (n=62/85) of ADHD symptom desisters and 71% (n=83/117) of ADHD symptom persisters were daily smokers, X^2 = .10, df(1), p = .76. For current smoking quantity among smokers, the association was also not statistically significant, X^2 = 1.24, df(3), p = .74. For example, 48% (n=42/87) of ADHD symptom desisters and 45% (n=53/119) of ADHD symptom persisters smoked ½ pack a day or more.

Discussion

The primary aim of the present study was to examine smoking behaviors that are prognostically-relevant for long-term smoking in a sample of individuals diagnosed with ADHD in childhood and followed prospectively into adolescence and early adulthood. We found important replication of higher rates of daily smoking, earlier initiation, and faster progression to daily smoking among those with ADHD histories compared to those without[1]. However, when we compared prognostically-relevant smoking behaviors important for long-term smoking outcome, between ADHD and nonADHD smokers, our findings were mixed. We discuss below the implications of these varied findings and provide suggestions for future research.

Our replication of previous reports of early initiation and fast progression (Kollins et al., 2005; Milberger et al., 1997; Molina & Pelham, 2003; Rohde et al., 2004; Sibley et al., 2014) provides important additional support for a previously observed behavioral pattern among ADHD smokers. Replication was needed because of important differences in methodologies across these studies. Some have followed children prospectively into adolescence and young adulthood from childhood (Molina et al., 2007; 2013; Sibley et al., 2014), while others have assessed initiation and progression retrospectively (Kollins et al., 2005; Milberger et al., 1997; Rohde et al., 2004). In our study, some participants were recalling their initiation behaviors over multiple years (e.g., those who were in their 20s when they were first interviewed), but others (the adolescents) were younger. Given that

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[1]Our results reflect surprisingly high rates of daily smoking even among the nonADHD participants and wide confidence intervals among the youngest age groups. Pennsylvania ranks high among other states with regard to smoking prevalence (range of 10.3% to 27.3%) with approximately 21.3% of adults over the age of 18 years (CDC, 2010) and approximately 18.6% of high school students (CDC, 2010) reporting current smoking. Nevertheless, even when taken within this context, our findings suggest important group differences in the development of smoking behavior.

self-reported age of onset tends to increase as participant age at the time of recall increases (O'Neil, Parra, & Sher, 2003), our findings are probably the most precise for those participants whose initiation occurred close-in-time to the first interview. Another methodologic consideration is that some studies (e.g. Kollins et al., 2005, Rohde et al., 2004) have relied on self-report of ADHD symptoms, which has been shown to be an underestimation of severity (e.g. Kooij et al., 2008). In the current study, ADHD was diagnosed in childhood using standardized interview and rating scale data from parents and teachers. Despite these differences, our findings and those of others consistently indicate that individuals with ADHD exhibit earlier and rapid uptake of smoking milestones.

Specific psychological, psychosocial, and biological vulnerabilities associated with ADHD may explain early experimentation with smoking and rapid progression to increasingly involved smoking behavior. For example, difficulties with delay discounting, impulsivity, novelty seeking, and associations with deviant peer groups are each considered risk factors for smoking (Doran et al., 2004; Marshal, Molina, & Pelham, 2003; Reynolds, et al., 2003; Shaw, Stringaris, Nigg & Leibenluft, 2014), and also characterize many individuals with ADHD (Hoza, 2007; Marshal & Molina, 2006; Marshal, Molina, & Pelham, 2003; Winstanley, Eagle & Robbins, 2006). The combination of an increased tendency to act impulsively, perhaps in the presence of strong rewards and/or new situations, and engagement with peers who are more likely to expose the individual to smoking, may contribute to smoking at a young age. Similarly, once initiated, individuals with ADHD may experience nicotine as more reinforcing than those without ADHD, due to an aberrant dopaminergic system (Sonuga-Barke, 2003; Tripp & Wickens, 2008; Volkow et al., 2009) that may result in a more rapid progression to regular smoking. While it is unclear exactly why individuals with a history of ADHD progress through the stages of smoking more quickly than those without ADHD, research that focuses on ADHD-related vulnerabilities, may highlight potential contributing factors.

Surprisingly we found no group differences in either quantity of cigarettes smoked or dependence scores. The lack of group differences may be due to our sample's relatively young age; their smoking behaviors may be developmentally "young" for this outcome and factors such as living at home with parents and smoking policies on school campuses, may affect consumption and dependence. If so, that may explain the equivocal nature of the literature on adolescents (Fuemmeler, et al., 2007; McClernon et al., 2008; Pomerleau et al., 2003). Lack of group differences in dependence scores may also be caused by under-reporting of impairment by individuals with ADHD histories (Sibley et al., 2012). Given that both lower consumption and dependence are associated with better success in quitting smoking, this pattern of results highlights the importance of future research prospectively following individuals with a childhood history of ADHD into adulthood to determine whether group differences emerge at older ages than in the current study. It is also possible that the absence of group differences is due to the small number of participants without ADHD who reported regular smoking; this small subsample may have limited our ability to observe group differences in dependence.

The ADHD group difference in timing of the first cigarette of the day was marginally statistically significant with those in the ADHD group slightly more likely to report smoking

within the first 30 minutes of the day. Some research has demonstrated that this specific behavior reflects dependence and predicts cessation and relapse (Baker et al., 2007). Behaviors typical of heavy dependence (e.g. smoking more frequently during first hours of waking; difficulty refraining from smoking in places where it is forbidden; Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991) are often just beginning to emerge during adolescence (Wellman, DiFranza, Savageau & Dussault, 2004). Though not statistically significant, these results suggest that for individuals with a history of ADHD, emerging dependence in adolescence may be reflected in this behavior and pertinent to the development of long-term dependence.

An important finding of the current study was the ADHD group differences in difficulties with craving and concentration (medium effect sizes) when deprived of cigarettes. The literature examining differences in craving and other withdrawal symptoms is limited and equivocal, with some studies reporting ADHD group differences (McClernon et al., 2011, Pomerleau et al., 2003) and others not (McClernon et al., 2008; McClernon et al., 2011; Pomerleau et al., 2003. The methodological differences among these studies may be important. Our findings were similar to those of Pomerleau and colleagues (2003) who also used retrospective self-report. On the other hand, McClernon and colleagues implemented laboratory-based abstinence paradigms using overnight (2008) and longer-term (2011) abstinence manipulations to investigate prospective effects on self-report withdrawal, craving, and cognition (computerized assessments). The aggregated findings across research groups suggest the presence of some important differences, particularly in craving and concentration, for ADHD versus nonADHD smokers experiencing deprivation. There is a clear need for additional research to employ more comprehensive and consistent assessments of withdrawal and craving during actual periods of deprivation to further elucidate these highly prognostic processes among smokers with ADHD.

Individuals with a history of ADHD did not differ in quit attempts compared to nonADHD smokers regardless of a longer duration of smoking. The young age of our sample may be a contributing factor. Smokers typically make several quit attempts prior to successful cessation in adulthood, with previous attempts predicting cessation (Hymowitz et al., 1997). Also, the literature suggesting that individuals with ADHD have more difficulty achieving cessation is based solely in adult samples (Pomerleau et al., 1995; Humfleet et al., 2005). Thus, the present sample may not have captured the pertinent timeframe for evaluating this stage of smoking. There is a need for prospective studies throughout adolescence and adulthood that examine quit attempts and related processes that may precede successful cessation.

ADHD symptom persistence was not associated with likelihood of being a daily smoker or with smoking amount. Given that many individuals with ADHD report a persistence of symptoms over time (Barkley, Fischer, Smallish, & Fletcher, 2002; Sibley et al., 2012a; 2012b) and this persistence from childhood has been associated with substance use (Molina & Pelham, 2003; Molina et al., 2007; Sibley et al., 2012a,b) including tobacco use (Breyer et al., 2014; Chang, Lichtenstein & Larsson, 2012), our findings were contrary to expectation. Perhaps, when considering the ADHD-smoking relationship over time, other contributing factors ought to be considered. For instance, it is widely accepted that factors such as

parenting and parental modeling, school functioning, and peer relationships drive a range of negative outcomes, including substance use (Derefinko & Pelham, 2014; Molina & Pelham, 2014). Additionally, the construct of impulsivity, known to influence substance use in general (Verdejo-Garcia, Lawrence, & Clark, 2008) and smoking specifically (Doran et al., 2004; VanderVeen et al., 2008), is not well captured by ADHD symptom reports which may partly explain inconsistent findings. Lastly, the present findings are intriguing in light of failure to consistently find beneficial effects of stimulant medication on smoking behavior among people with ADHD (e.g. Rush et al., 2005; Schoenfelder, Faraone, & Kollins, 2014; Winhusen et al., 2010). ADHD symptoms may have little to do with smoking-related behavior once the initial uptake process has crystallized into daily smoking.

Our findings of a much greater likelihood of smoking at young ages and increased craving and difficulty concentrating during abstinence highlight the need for prevention and treatment considerations in this population. Specifically, children with ADHD may benefit from preventative measures early in adolescence before smoking experience begins to accumulate. Smoking prevention programs have been developed for adolescents (e.g. Bruvold, 1993); however, there are no prevention programs to our knowledge specifically designed for smokers with a history of ADHD. Treatment/prevention efforts ought to target factors that may mediate the relationship between ADHD and smoking. For example, Molina and colleagues (2005) demonstrated that poor coping skills and low parent support partially mediated the relationship between ADHD and smoking. The authors suggest that these "problem-solving deficits" may partially explain why this group of individuals is at risk for smoking. As such, these deficits may be important, clinically malleable treatment targets in preventing and extinguishing early smoking behaviors (e.g. Evans, Axelrod & Langberg, 2003; Griffin, Botvin, Nichols, & Doyle, 2003). Additionally, parental smoking has been linked to adolescent smoking (Chassin et al., 2002). Parental cessation and antismoking attitudes may lower the risk of adolescent smoking. Focusing on maintenance factors (abstinence-related experiences) may be especially beneficial for smokers with a history of ADHD. For example, it has been suggested that withdrawal-related cognitive deficits should be targeted behaviorally and/or pharmacologically (e.g. Sofuoglu, 2013). Overall, it is clear that future research needs to better target both prevention and cessation strategies for smokers with a history of ADHD.

While the present findings replicate and extend the current literature on the ADHD-smoking relationship using a sample of participants across a variety of ages (some of which are recalling smoking behaviors relatively recently), there are important limitations to be considered. Small sample sizes for some of our questions limited our power to detect group differences. In addition, bioverification of smoking reports may have increased reports of smoking. Given that the ADHD sample was drawn from a tertiary care specialty treatment clinic, these participants may represent a more severe presentation than an epidemiological sample (although we note that partial indicators of severity, namely conduct disorder and ADHD symptom persistence, did not drive our main findings). Finally, there may be some error in the recall of smoking behaviors, such as age of initiation and quit attempts, especially given reporting challenges with this population (Sibley et al., 2012). Even with these limitations, the present study provides an important demonstration that ADHD is a significant risk factor for cigarette smoking across most phases of smoking behaviors, and as

such it ought to be targeted in prevention and treatment efforts. Our findings point to smoking behaviors that may maintain smoking differentially for those with a history of ADHD; however, more research is needed to better understand the mechanisms underlying the vulnerability for early initiation and progression to smoking as well as the specific unfolding of dependence with age and smoking experience. The present study highlights how future research may better address the question of *how* and *why* individuals with ADHD are at risk for smoking. Identifying the mechanisms at the core of the ADHD-smoking association will better inform treatment for smokers with ADHD.

Acknowledgments

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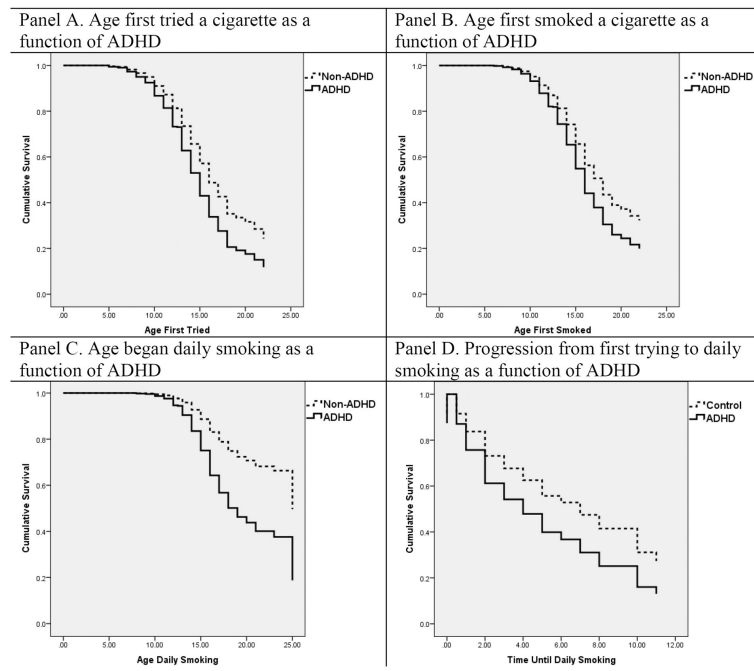
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Panel A. Age first tried a cigarette as a function of ADHD

Panel B. Age first smoked a cigarette as a function of ADHD

Panel C. Age began daily smoking as a function of ADHD

Panel D. Progression from first trying to daily smoking as a function of ADHD

Figure 1.
Cox Regressions of Initiation and Progression

Table 1

Rates of ever trying a cigarette, ever smoking a cigarette, and ever smoking daily, by diagnostic group and age group.

	Mean Age (SD)	ADHD	nonADHD	*Wald*	*Exp(B)*
11–14 year olds	13.0 (1.0)	N = 69	N = 56		
Tried a cigarette		41%	14%	7.2**	4.0
Smoked a cigarette		19%	5%	3.1+	3.6
Daily smoking[a]		9%	0%	na	na
15–17 year olds	16.0 (.8)	N = 94	N = 64		
Tried a cigarette		63%	42%	4.1*	2.1
Smoked a cigarette		54%	36%	3.6+	2.0
Daily smoking		33%	5%	10.9***	8.7
18–20 year olds	18.8 (.8)	N = 124	N = 84		
Tried a cigarette		73%	74%	.75	.73
Smoked a cigarette		65%	66%	1.1	.71
Daily smoking		48%	32%	.46	1.3
21+ year olds	22.5 (1.5)	N = 73	N = 34		
Tried a cigarette		92%	82%	.57	1.7
Smoked a cigarette		85%	79%	.12	1.3
Daily smoking		68%	41%	5.9**	3.6

Note.

[a] Due to low sample size in nonADHD group, analyses were not conducted.

+ $p < .10$

* $p < .05$,

** $p < .01$,

*** $p < .001$.

Table 2

Descriptive Information for Reported Smoking Behaviors by ADHD Group.

	ADHD	nonADHD	*p* value	Cohen's *d*
Dependence				
NDSS	−1.2 (.6)	−1.1 (.5)	ns	.18
FTND	3.9 (1.9)	3.6 (2.0)	ns	.15
Withdrawal (Difficulty Concentrating)	2.0 (1.1)	1.5 (1.0)	.02	.48
Craving	2.2 (1.1)	1.8 (1.1)	.04	.36
Quit Attempts				
Number of Attempts	3.5 (7.1)	4.8 (16.9)	ns	.10
Length of Attempt	3.7 (1.6)	4.1 (1.6)	ns	.25

Note. Values represent mean values, parenthesis reflect standard deviation. Sample sizes are as follows: Dependence ADHD n=111, nonADHD n=31; Withdrawal ADHD n=208, nonADHD n=109; Craving ADHD n=208, nonADHD n=109; Quit Attempts ADHD n=112, nonADHD n=34.