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Discrepancies in the Validity of Self-Reported Cigarette Smoking in Adults with and without ADHD

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Abstract

Objective—Attention-deficit/hyperactivity disorder (ADHD) is associated with an increased smoking prevalence and impairments in executive function, which may negatively affect the validity of self-reported smoking rates. This study compares the utility of self-reported smoking with salivary cotinine in adult smokers and non-smokers with and without ADHD.

Methods—Participants ($N = 82$) were adult smokers and nonsmokers with and without ADHD ($n = 35$ ADHD and $n = 47$ controls) from an observational study. Odds ratios (*ORs*) for accuracy of self-reported smoking compared to salivary cotinine were calculated using diagnosis (ADHD versus control), gender, age, education, employment, and number of cigarettes per day as predictors. Post-hoc analysis stratified sensitivity, specificity, and accuracy of self-reported smoking in individuals with ADHD and without ADHD.

Results—The initial analysis identified education as a significant independent predictor of odds of accuracy $OR = 6.22$, $p = .013$, after adjusting for diagnosis, gender, age, employment, and cigarettes per day. Post-hoc analysis revealed that sensitivity, specificity and accuracy of self-reported smoking was 100% for individuals with ADHD who had more than high school education compared to those with high school or less, which was 83.3%, 45.5%, and 65.2%, respectively. Self-reported smoking of control participants with greater than a high school education had a sensitivity of 85.7%, a specificity of 91.7%, and an accuracy of 88.5%. Control participants with a high school or lower education had a sensitivity of 54.6%, a specificity of 90%, and an accuracy of 71.4% for their self-reported smoking.

Conclusion—Individuals with ADHD and high school or lower education showed the lowest specificity and accuracy in their self-reported smoking, which may affect documented smoking prevalence rates. This is a secondary analysis of data collected as part of a clinical trial registered as Clinicaltrials.gov Identifier at www.clinicaltrials.gov.

Keywords

cotinine; education; smoking prevalence; executive function; accuracy; health disparities

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Disclosures

The authors report no relevant financial conflicts.

Introduction

Self-report surveys on smoking rates are generally considered cost-efficient, quick, and reliable (Hoseini et al., 2016; Vartiainen, Seppala, Lillsunde, & Puska, 2002; Yeager & Krosnick, 2010) but age, education, and frequency of smoking have been shown to affect accuracy (Caraballo, Giovino, Pechacek, & Mowery, 2001; Gerritsen et al., 2015; Klesges, Klesges, & Cigrang, 1992). Historically, self-reported smoking amongst the general population shows high levels of sensitivity and specificity. Sensitivity is the ability of a test to correctly identify individuals with a condition (true positives), whereas specificity is the ability to correctly identify those without the condition of interest (true negatives; Akobeng, 2007). According to a 1994 meta-analysis, sensitivity and specificity were on average 87% and 89%, respectively, when compared to biochemical markers (Patrick et al., 1994). However, more recent studies have shown that these self-reports underestimate the prevalence of smoking (Connor Gorber, Schofield-Hurwitz, Hardt, Levasseur, & Tremblay, 2009). In a study assessing the validity of smoking self-reports across different countries, the United States was shown to underestimate sensitivity and specificity by 0.6% (West, Zatonski, Przewozniak, & Jarvis, 2007). People are thought to underreport their smoking due to perceived social pressure (Fendrich, Mackesy-Amiti, Johnson, Hubbell, & Wislar, 2005; Gerritsen et al., 2015). Furthermore, concerns have been raised about the subjectivity and recall error associated with self-reports (Benowitz, Bernert, Caraballo, Holiday, & Wang, 2009). Recall error and reduced memory function are frequently associated with attention-deficit/hyperactivity disorder (ADHD; Pollak, Kahana-Vax, & Hoofien, 2008), which has a prevalence of 2.5% in adults (American Psychiatric Association, 2013) who also have a smoking prevalence rate of 40% (Pomerleau, Downey, Stelson, & Pomerleau, 1995; McClave, McKnight-Eily, Davis, & Dube, 2010). Previous research has shown that individuals with ADHD had a higher incidence of false memories than control participants (Soliman & Elfar, 2014). Inaccuracies in self-reports have important implications for smoking prevalence rates and tobacco related disease statistics (Yeager & Krosnick, 2010). Biomarkers of nicotine intake via tobacco smoke are more objective, such as cotinine – a nicotine metabolite, which is detectable in saliva for up to 2–3 days (Bramer & Kallungal, 2003; Carey & Abrams, 1988).

The aim of the study was to examine discrepancies in the validity of self-reported smoking compared to salivary cotinine levels in individuals with and without ADHD. It was hypothesized that accuracy of self-reported smoking is a function of age, education, frequency of smoking and diagnosis (Pollak et al., 2008; Stein et al., 2002). Based on the initial model, we performed follow-up analyses that evaluated discrepancies in specificity, sensitivity, and accuracy in individuals with and without ADHD.

Method

Data

A total of 82 participants were recruited from the community using advertisements, flyers, and referrals from healthcare professionals as part of a neuroimaging study on ADHD and smoking (Gehricke et al., 2017). The study inclusion criteria were male and female current

smokers and nonsmokers, ages 18 to 45, with or without a diagnosis of ADHD. The study excluded pregnant women or women who were planning on pregnancy, individuals with any chronic or major medical illness or any mental disorder that required medication (other than stimulant medication), as well as non-English speaking individuals. The study was explained to all participants before informed consent was obtained. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Institutional Review Board of the University of California, Irvine. The participants represented various racial groups, both genders, and matched the criteria of either an ADHD diagnosis or no diagnosis. Each participant was assessed according to DSM-IV criteria by a licensed psychologist (J-G.G.) using the Structural Clinical Interview for DSM Disorders (First MB, 2002), and the QUEST Method (Wigal et al., 2007). The majority of participants with ADHD were diagnosed with the predominantly combined subtype (54.3%, $n = 19$) compared to the predominantly inattentive subtype (40.0%, $n = 14$) and the hyperactive-impulsive subtype (5.7%, $n = 2$). In addition, 25.7% ($n = 9$) of participants with ADHD were taking stimulant medications such as Adderall (14.3%, $n = 5$) and Ritalin (11.4%, $n = 4$). See Table 1 for more details on participant characteristics.

Measures

Participants were surveyed about their smoking status (smoker versus nonsmoker), average number of cigarettes smoked per day for the last 30 days, education, employment status, and current medication intake. The administered questionnaire contained a total of 29 items including questions about general health behaviors such as physical exercise and mental well-being, with the main questions addressing smoking habits appearing early on in the survey. Participants took roughly 5–10 minutes to complete the entirety of the questionnaire. Participants were also asked to provide saliva samples on four separate days. The following cotinine cutoffs were used: 4.85 ng/ml for Whites, 5.92 ng/ml for African-Americans, and 0.84ng/ml for Mexican-Americans (Benowitz et al., 2009). Salivary cotinine is minimally invasive in nature and has increased sensitivity (Connor Gorber et al., 2009). Since salivary cotinine is a comparable measure to plasma cotinine (Benowitz et al., 2009; Bernert et al., 2000; Jarvis et al., 2003; Parzynski et al., 2008; SRNT, 2002), the cotinine cutoffs proposed by Benowitz and colleagues (Benowitz et al., 2009) were used for analysis. The salivary sample was collected, stored in a freezer, and analyzed by Salimetrics as cotinine values in ng/mL units. See Table 1 for more details.

Analysis

This study was an ad-hoc examination of salivary cotinine and self-reported smoking data collected from a neuroimaging study, which recruited a relatively equal number of smokers and nonsmokers with and without ADHD. The primary aim of this exploratory analysis was to assess the accuracy of self-reported smoking in each group. The evaluation of sensitivity, specificity and accuracy within the subgroups was the primary endpoint analysis. Analysis of potential predictors of individual level accuracy was exploratory and could inform design of future studies.

Participants who reported being smokers and had measured cotinine levels above the cutoff were considered *True Positive*, while those who reported being non-smokers and had

cotinine levels below the cutoff were considered *True Negative*. Participants who reported being non-smokers but had cotinine values that indicated levels typical of a smoker were *False Negative*, while those who reported smoking and did not meet the cotinine threshold were *False Positive*. Sensitivity, specificity and accuracy was calculated according to established formulas (Akobeng, 2007) separately for individuals with ADHD and controls. More specifically, sensitivity was defined as *True Positive*/(*True Positive* + *False Negative*). Conversely, specificity was defined as *True Negative*/(*True Negative* + *False Positive).* Using the specificity and sensitivity data, accuracy was measured for each ADHD and control group using (*True Positive* + *True Negative*)/(*True Positive* + *False Positive* + *True Negative* + *False Negative*).

For the independent predictors analysis, accuracy was defined on an individual level using a binary variable where 1 = *Accurate* (True Positive or True Negative) and 0 = *Not Accurate* (False Positive or False Negative). The distribution of level of education in years revealed a median split that corresponded with two categories: high school or less/more than high school (i.e., college). The range of ages spanned adulthood and the distribution lent itself to examining younger, approximately college-age, adults (up to age 23) to older adults (age 24 and over). Thus, both education and age were entered as binary variables. The sample was predominantly White (73%). Asian-Americans made up 17% of the sample, Chicanos 6%, Native Americans 2%, and African Americans 1%. Investigation of both three-level race (White/Asian/Other) and binary race (White/non-white) indicated no significant relationship between race and any of accuracy, ADHD/control, or smoking status. Thus, education, age, and race were entered as binary variables. For age, participants were divided into two groups: 23 years of age or younger, and older than 24 years of age; education was divided into two categories: high school or less, and more than high school; and race was indicated as White or non-White. Odds ratios were calculated for age, education, race, frequency of smoking, and clinical diagnosis with SAS (SAS Institute Inc.) using accuracy of self-reported smoking (currently smoking versus nonsmoking) versus their average cotinine levels across 4 consecutive days. Hypothesis testing was conducted at a p value of .05, two-tailed. Employment was also included in the model to take into account the significant difference between individuals with ADHD and controls ($p = .030$). Based on the findings from the initial model, stratified analyses were performed and contingency tables created to further examine the variation in sensitivity, specificity and accuracy among diagnostic and education subgroups.

Results

All subjects had complete data for each of the independent predictors of accuracy ($N = 82$) and were included in the logistic regression (see Table 2). On an individual level, participants in each diagnosis group exhibited similar accuracy of smoking status (binary variable): participants with ADHD (22.9%) and control participants (19.5%), $\chi^2(1) = .17$, $p = .683$. Education was a significant independent predictor of odds of accuracy, $OR = 6.22$, Wald $\chi^2(1) = 6.2$, $p = .013$, after adjusting for diagnosis, gender, age, race, employment, and cigarettes per day. The other factors in the model were not independent predictors of accuracy. A model investigating the interaction of diagnosis and education on accuracy yielded no significant difference in the education effect between the subgroups ($p = .976$).

Table 3 shows the frequency of individuals with and without ADHD being above/below cutoff by education and self-reported smoking status. In the follow up analysis, individuals with ADHD and a high school or less education showed a sensitivity of 83.3%, specificity of 45.5%, and accuracy of 65.2% (Table 4). In contrast, individuals with ADHD and more than a high school education, sensitivity, specificity, and accuracy were 100%. Control participants with a high school or lower education showed a sensitivity of 54.6%, a specificity of 90%, and an accuracy of 71.4%. Control participants with more than a high school education showed a sensitivity of 85.7%, a specificity of 91.7%, and an accuracy of 88.5%.

Discussion

Education was the only independent predictor of self-reported smoking accuracy which corroborates previous findings (Caraballo et al., 2001; Gerritsen et al., 2015; Klesges et al., 1992). Age and smoking frequency were not identified as independent predictors due to the relatively young age and modest smoking frequency of the participants. However, stratified analysis of the utility of self-reported smoking yielded differential results for adults with ADHD compared to those without ADHD. More specifically, the findings suggest that education may be an independent predictor of accuracy particularly in individuals with ADHD who had a 34.8% difference between those who had more than a high school education compared to those who had a high school education or less. In individuals without ADHD, this difference was 17.0%. Intriguingly, individuals with ADHD who had more than a high school education had the highest accuracy, followed by controls with more than a high school education, then controls with a high school education or less, and finally individuals with ADHD who had a high school education or less. These findings corroborate previous studies that lower levels of education reduce smoking accuracy (Caraballo et al., 2001; Gerritsen et al., 2015; Klesges et al., 1992), particularly in individuals with ADHD. Although ADHD has been associated with subjective recall bias (Soliman & Elfar, 2014), the current findings suggest that this association may be affected by education.

Besides the differences in accuracy, individuals with ADHD with a high school education or less had higher sensitivity and lower specificity compared to controls with similar educational attainment. As depicted in Table 3, the lower specificity in individuals with ADHD with a high school education or less was due to the larger proportion of False Positives ($n = 6$ out of 35 participants) compared to the control group ($n = 1$ out of 47 participants). Correspondingly, higher sensitivity in this group was due to a lower proportion of False Negatives compared to the control group ($n = 2$ for ADHD versus $n = 5$ in control). These data suggest that among those who have a high school education or less, individuals with ADHD have a tendency to over-report their smoking status whereas those without ADHD (i.e., the control smokers in our study) may be under-reporting their smoking. More research is necessary on the link between ADHD, education and the accuracy of reporting (e.g., of substance use, medication intake, etc.) by examining the underlying prefrontal cortex functioning as was done in previous research on memory function (Abe et al., 2008).

The findings suggested that education may be a significant factor in determining the utility of self-reported smoking in individuals with and without ADHD. The utility of self-report

was high in individuals with more than a high school education, in particular for those with ADHD. But individuals with ADHD and a high school education or less were less likely to be correctly identified as nonsmokers based on their self-report. In contrast, individuals without ADHD and a high school education or less were less likely to be correctly identified as smokers based on self-report. Such sensitivity and specificity data fall far below that of 87.5% sensitivity and 89.2% specificity averages found in a previous meta-analysis comparing the accuracy of self-reports to measured cotinine (Patrick et al., 1994). However, the small sample size when divided into subgroups limits generalizability of the findings to the larger convenient area. In addition, individuals with ADHD showed more heterogeneity in years of education and employment compared to controls, which may have affected the results. Although it remains unclear if secondhand smoke (SHS) exposure alone could raise the cotinine levels of non-smokers enough to exceed the cutoffs utilized, SHS was not taken into account in this study, which may have affected cotinine values in participants, particularly in those with ADHD and high school education or less (Lindsay, Tsoh, Sung, & Max, 2016).

In summary, the findings revealed that the validity of self-reported cigarettes use may be significantly affected by educational attainment in individuals with and without ADHD. The data suggests that self-reported smoking rates are particularly problematic when the majority of individuals in a population have an educational level of high school or less. This may affect self-reported smoking rates in individuals with ADHD due to the documented lower educational outcomes in this population (Loe & Feldman, 2007). Thus, while self-reported smoking surveys for individuals with higher education provide a relatively accurate estimate of real behavior, independent of ADHD, salivary cotinine collection may be necessary to validate smoking in those with a high school education or less.

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Table 1

Participant Characteristics

	ADHD (*n* = 35)	Control (*n* = 47)
Demographics		
Ages, years (*M* ± *SD*) (min, max)	24.83 ± 4.51 (21, 41)	23.91 ± 3.53 (18, 39)
>= 24 years old (%, *n*)	40.0%, 14	48.9%, 23
Male/Female (*n*)	30/5	35/12
Race/Ethnicity		
White (%, *n*)	77.1%, 27	70.2%, 33
Asian American (%, *n*)	14.3%, 5	19.2%, 9
Other (African, Chicano, Native American) (%, *n*)	8.6%, 3	10.6%, 5
Education, years (*M* ± *SD*)	13.94 ± 3.29	14.87 ± 1.97
More than high school (%)	34.3%, 12	55.2%, 26
Employed (%)	57.1%, 20	80.9%, 38
Smoking measures		
Mean cotinine (ng/ml) (*M* ± *SD*)	69.84 ± 107.68	57.96 ± 78.78
Self-reported cigarettes per day (*M* ± *SD*)	6.50 ± 7.16	3.94 ± 6.52
Self-reported smokers (%, *n*)	60.0%, 21	42.6%, 20
Mean cotinine (ng/ml) (*M* ± *SD*)	100.06 ± 111.52	104.99 ± 84.75
Self-reported cigarettes per day (*M* ± *SD*)	10.83 ± 6.15	9.25 ± 7.14
Self-reported non-smokers (%, *n*)	40.0%, 14	57.5%, 27
Mean cotinine (ng/ml) (*M* ± *SD*)	24.53 ± 86.66	23.13 ± 52.65
Self-reported cigarettes per day (*M* ± *SD*)	0 ± 0	0 ± 0

Note. ADHD = attention-deficit/hyperactivity disorder; M = Mean; SD = standard deviation.

Table 2

Adjusted Odds Ratio of Accuracy

Effect	Adjusted odds ratio estimates[a] (95% Wald confidence interval)	Wald χ^2 *(df = 1)*	*p*
Diagnosis (ADHD vs. control)	1.313 [0.373, 4.616]	0.1799	.672
Gender (female vs. male)	1.687 [0.401, 7.095]	0.5094	.475
Age (≤ 23 years old vs. ≥ 24 years old)	1.810 [0.521, 6.284]	0.8742	.350
Race/ethnicity (White vs. non-White)	1.204 [0.301, 4.812]	0.0678	.793
Education (high school or less vs. more than high school)	6.200 [1.470, 26.15]	6.1721	.013
Employed	0.443 [0.106, 1.849]	1.2466	.264
Cigarettes/day	0.951 [0.860, 1.051]	0.9748	.323

Note. ADHD = attention-deficit/hyperactivity disorder

[a]Odds ratios for accuracy were adjusted for diagnosis, gender, age, race, employment, and cigarettes per day.

Table 3

Self-Reported Smoking and Cotinine Cutoffs by Education

		Self-reported status	Did cotinine exceed cutoff[a] indicative of smoking?	
			No	Yes
ADHD	High school or less	Nonsmoker	5	2
		Smoker	6	10
	More than high school	Nonsmoker	7	0
		Smoker	0	5
Control	High school or less	Nonsmoker	9	5
		Smoker	1	6
	More than high school	Nonsmoker	11	2
		Smoker	1	12

Note. ADHD = attention-deficit/hyperactivity disorder.

[a]Cotinine cutoffs by race are 4.85 ng/ml for Whites, 5.92 ng/ml for African Americans, and 0.84 ng/ml for Mexican-Americans (Benowitz et al., 2009).

Table 4

Utility of Self-Reported Smoking versus Cotinine Levels by Education in Adults with ADHD and Controls

	Current smoker based on cotinine (*n* =42)	**Current smoker based on self-report (*n* = 41)**	**Sensitivity *True Positive*/(*True Positive* + *False Negative*)**	**Specificity *True Negative*/(*True Negative* + *False Positive*)**	**Accuracy (*True Positive* + *True Negative*)/(*True Positive* + *False Positive* + *True Negative* + *False Negative*)**
ADHD					
High school or less	52.2%, *n* = 12	65.2%, *n* = 15	83.3%	45.5%	65.2%
More than HS	41.7%, *n* = 5	41.7%, *n* = 5	100%	100%	100%
Control					
High school or less	52.4%, *n* = 11	33.3%, *n* = 7	54.6%	90.00%	71.4%
More than HS	53.9%, *n* = 14	41.7%, *n* = 14	85.7%	91.7%	88.5%

Note. ADHD = attention-deficit/hyperactivity disorder; HS = high school.