The association between cigarette smoking and DSM-IV nicotine dependence among first year college students

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Abstract

Aims: This study was undertaken to evaluate the association between cigarette smoking behavior and DSM-IV nicotine dependence.

Design: Drawing on a sample of first year college students selected for representation across a continuum of smoking behavior, current DSM-IV nicotine dependence criteria were assessed among participants reporting any smoking in the preceding week on a web-based survey protocol. Logistic regression and receiver operator characteristic analyses were used to estimate the overall concordance between smoking and DSM-IV nicotine dependence.

Findings: Relationships were supported between both quantity and frequency of smoking in the past week and DSM-IV nicotine dependence showing higher prevalence of dependence at higher levels of use ($p < 0.05$). While the highest prevalence of nicotine dependence was seen among those reporting the most frequent and heavy smoking, a substantial number of participants reporting daily and/or heavy smoking did not meet criteria for nicotine dependence. Conversely, nicotine dependence was seen among a subgroup of participants reporting relatively low levels of non-daily smoking. Diagnostic concordance was found to be moderate for both quantity and frequency and was not improved by combining information from these two indices.

Conclusions: Aside from confirming DSM-IV nicotine dependence at relatively low levels of smoking, these results may be used to inform research aimed at identifying samples of nicotine dependent youth across the range of smoking levels.

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Keywords: Nicotine dependence; Smoking; Exposure

1. Introduction

Previous research has supported a positive relationship between substance use and a diagnosis of substance dependence in which prevalence of dependence is generally higher at higher levels of use. This association has been supported for alcohol (Grant, 1993; Woody et al., 1993), marijuana (Chen et al., 1997) cocaine (Woody et al., 1993; Chen and Kandel, 2002) and nicotine (Stanton, 1995; Kandel and Chen, 2000) and supports repeated or chronic use as a core feature in the phenomenology of substance dependence. Epidemiologic studies comparing prevalence of dependence across substances has shown nicotine to have the highest dependence liability (i.e. highest prevalence of dependence among those exposed to the substance). For example, a diagnostic and statistical manual (DSM) substance use disorder field trial showed that for individuals drawn from treatment and community settings, a higher proportion of smokers...
Relatively little is known about the level of smoking that is necessary or sufficient to result in nicotine dependence (DiFranza et al., 2000; Karp et al., 2005). Dependence criteria are often evaluated only if respondents meet clearly established smoking patterns (e.g. daily use), thus constraining the range of smoking levels that can be examined. Available research exploring the use/dependence relationship has revealed the presence of individual differences in susceptibility to dependence (Colby et al., 2000a,b). For example, based on a longitudinal study of young adolescents, symptoms of nicotine dependence were reported in a subset of novice smokers only weeks following the onset of once per month smoking behavior (DiFranza et al., 2000a,b). For example, based on a longitudinal study of young adolescents, symptoms of nicotine dependence were reported in a subset of novice smokers only weeks following the onset of once per month smoking behavior (DiFranza et al., 2000a,b). Further, in a study by Kandel and Chen (2000), the prevalence of nicotine dependence during a period of compressed change in terms of substance use provides a unique opportunity to evaluate the more general relationship between smoking and nicotine dependence. While reciprocity of the relationship (i.e. the degree to which smoking behavior drives risk for nicotine dependence versus the degree to which symptoms of nicotine dependence drive smoking behavior) cannot be easily disentangled within the present data set, the assessment of nicotine dependence across levels of smoking during a period of compressed change in terms of substance use provides a unique opportunity to evaluate the more general association between smoking and nicotine dependence.

In the present investigation, we examine the association between DSM-IV nicotine dependence and level of smoking. The purpose was to estimate: (1) the prevalence of nicotine dependence at various smoking levels; (2) the diagnostic concordance between smoking quantity/frequency and nicotine dependence. Among the important research issues that surface in studies of this type are: (a) the use of cross-sectional versus longitudinal data (this is a cross-sectional study); (b) the time frame in which nicotine dependence and smoking behavior are measured; (c) issues of reciprocity in which nicotine dependence is both driven by as well as the result of smoking.

2. Method

2.1. Participants

Participants were selected from responses to a screener survey (n = 4690) administered to first year students during the orientation program at a large state university in the summer of 2002 (response rate 71%). Recruitment for the screener survey began with an oversided postcard mailed in mid-May to all incoming freshmen. The postcard told potential participants that they would have the opportunity to complete a confidential 10-min survey titled “College Freshmen Health Behavior Survey” when they were on campus for orientation activities. They were told that the survey would be used to identify people who would be invited to participate in a major study on healthy living that would begin in August when they arrived at university for the school year. They were also informed that they would be paid $5.00 in cash for completing the survey.

On campus, posters announcing the project were placed at all locations frequented by orientation participants. In addition, the counselors conducting all of the school activities for day on campus made a brief announcement reminding students about the survey and the survey locations. A flyer describing the survey was placed in each orientation packet distributed to students. In addition, flyers were placed on campus sidewalks near key buildings. Signboards were located outside and inside the two sites for survey administration.

In all, 2001 (42%) individuals completing the screener reported at least some experience with smoking (i.e. one or more puffs lifetime) and were invited by mail to participate in the study. Nine hundred and twelve (46%) of these individuals completed the baseline survey and were asked to take part in 35 weekly web-based surveys throughout their first year. The overall response rate for 35 weeks was 87%, 90% when students were on campus, 76% when they were not (i.e. fall, winter and spring breaks). The sample was 48% female and 68% of the participants were permanent residents of Indiana. Ninety percent of the sample was Caucasian, 5% were Asian and 3% were Black. The present analyses are based on data collected during week 14 of the survey which was the assessment that included DSM-IV nicotine dependence and coincided with the end of the first academic semester (n = 859, response rate = 94%). Fig. 1 displays the participation at each step of the selection and participation process.

2.2. Measurement

2.2.1. Smoking quantity and frequency. Seven-day retrospective reports of cigarette smoking were obtained. Using the web-based survey protocol, participants were asked to enter the “number of cigarettes you smoked” on each day of the preceding week. Aggregate past week smoking variables addressing both quantity (i.e. total number of cigarettes smoked) and frequency (i.e. number of days smoked) were created from these responses.

2.2.2. Nicotine dependence. DSM-IV nicotine dependence was assessed using a self-administered version of the Composite International Diagnostic Interview Tobacco Module (WHO, 1994) known as the TTURC nicotine dependence inventory. This instrument assesses nicotine dependence in terms of the seven criteria specified by the DSM-IV diagnosis of substance dependence (APA, 1994) For the present study, dependence criteria were assessed among all participants reporting any smoking during the preceding 7 days. Given our interest in the association between a broad range of smoking quantity and frequency and the endorsement of nicotine dependence criteria, daily use of nicotine was not required for the administration of the TTURC nicotine dependence inventory. An individual was classified as dependent if he/she experienced at least three of the seven dependence criteria associated with their smoking behavior (i.e. tolerance, withdrawal or smoking to avoid or reduce withdrawal, smoking in larger amounts or longer than intended, persistent desire or unsuccessful efforts to cut down, great deal of time spent to obtain, use or recover from smoking, activities given up or reduced, and smoking despite physical or psychological problems caused or exacerbated by smoking).

Table 1 presents the DSM-IV criteria and the corresponding questions. Response categories included “not at all,” “a little bit,” “somewhat,” and “quite
Finally, receiver operator characteristic (ROC) curves were used to estimate diagnostic concordance between smoking and nicotine dependence across the range of smoking levels with the area under the curve estimate (AUC) (Rey et al., 1992). The AUC can range from 0.5 (chance prediction) to 1.0 (perfect prediction) and represents the probability that a randomly selected individual with nicotine dependence will have a higher value (i.e. on quantity or frequency) than a randomly selected individual without nicotine dependence. The AUC is evaluated with the following guidelines: 0.50–0.70 (low concordance); 0.70–0.90 (moderate concordance); >0.90 (high concordance). To examine the joint contribution of quantity and frequency, each index was converted to a z-score (mean of 0 and standard deviation of 1) and then combined into a quantity/frequency composite by summing the standardized variables.

3. Results

3.1. Prevalence of nicotine dependence and smoking levels

3.1.1. Total sample. The prevalence of smoking and nicotine dependence for the total sample and among past week smokers is presented in Table 2. Thirty-eight (4.4%) of the total sample met criteria for nicotine dependence, and 119 (13.9%) met at least one nicotine dependence criterion. Males were more likely than females to have smoked in the preceding week and to meet at least one nicotine dependence criterion (p < 0.05) (Table 2). Males and females, however, showed a similar prevalence of DSM-IV nicotine dependence diagnoses.

3.1.2. Past week smokers. Overall, 176 (20.5%) participants reported smoking in the preceding 7 days. Past week smokers reported smoking between 1 and 210 cigarettes (M = 28.1, S.D. 33.84), with a median of 17 cigarettes. Smoking occurred on an average of 4.3 days (S.D. 2.36) and 42 (23.9%) participants smoked daily during the preceding week. The correlation between smoking quantity and frequency was r = .64 (p < .0001). Males and females reported statistically similar smoking quantities (F(1, 174) = 0.01, p = 0.91) and frequency (F(1, 174) = 0.03, p = 0.86). The 1-month prevalence of nicotine dependence among past week smokers was 21.6%; these participants endorsed 1.5 (S.D. 1.69) dependence items on average (participants with DSM-IV nicotine dependence M = 4.2 items, S.D. 1.25 and participants without DSM-IV nicotine dependence M = 0.8 items, S.D. 0.77). Again, nicotine dependence and the number of dependence items endorsed were similar for males and females (Table 2).

In terms of smoking history, more than half of the past week smokers (n = 93, 52.8%) had engaged in daily smoking for at least 30 days upon entering the university, and another 59 (33.5%) had smoked at least once a month for 3 months or longer. The remaining 24 participants (13.6%) had never reached monthly or daily smoking levels before entering the university. Past week smokers (n = 176) were examined in all subsequent logistic regression and ROC models.

3.2. Association between nicotine dependence and smoking quantity

Logistic analyses with polynomial contrasts were used to test the association between DSM-IV nicotine dependence diagnosis...
A maladaptive pattern of substance use, leading to clinically significant impairment or distress, as manifested by three or more of the following occurring at anytime in the same 12-month period:

- Tolerance as defined by either of the following:
  - (a) need for markedly increased amounts to achieve intoxication or desired effect
  - (b) markedly diminished effect with continued use of the same amount

- Withdrawal, as manifested by either of the following (a) or (b):
  - (a) Characteristic withdrawal syndrome (both A and B)
    - A. Daily use of nicotine for at least several weeks
    - B. Abrupt cessation or reduction in the amount of nicotine use, followed within 24 h by four or more of the following signs:
      - (1) Dysphoric or depressed mood
      - (2) Insomnia
      - (3) Irritability, frustration or anger
      - (4) Anxiety
      - (5) Difficulty concentrating
      - (6) Restlessness
      - (7) Decreased heart rate
      - (8) Increased appetite or weight gain
  - (b) The same or closely related substance taken to relieve or avoid withdrawal symptoms

- The substance is often taken in larger amounts or over a longer period than was intended

- There is a persistent desire or unsuccessful attempts to cut down or control substance use

- A great deal of time is spent in activities necessary to obtain the substance or recover from its effects

- Important social, occupational, or recreational activities are given up or reduced because of substance use

- The substance use is continued despite knowledge of having a persistent or recurrent physical or psychological problem that is likely to have been caused or exacerbated by the substance

Table 1

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Tolerance as defined by either of the following (a)</td>
<td>Compared to when you first started smoking you need to smoke more now in order to feel satisfied or get the same effect? You find you can smoke more without experiencing effects like nausea, lightheadedness, or dizziness?</td>
</tr>
<tr>
<td>2. Withdrawal, as manifested by either of the following (a) or (b) (a)</td>
<td>Excluded</td>
</tr>
<tr>
<td>3. The substance is often taken in larger amounts or over a longer period than was intended</td>
<td>How often do you... Smoke even though you promise yourself you won’t? How often do you... Smoke more frequently or for more days in a row than you intend?</td>
</tr>
<tr>
<td>4. There is a persistent desire or unsuccessful attempts to cut down or control substance use</td>
<td>How often do you... Try to stop or cut down on your smoking but are unable to do so?</td>
</tr>
<tr>
<td>5. A great deal of time is spent in activities necessary to obtain the substance or recover from its effects</td>
<td>How often do you... Have periods of several days or more when you chain-smoke, that is, start another cigarette as soon as you finish one?</td>
</tr>
<tr>
<td>6. Important social, occupational, or recreational activities are given up or reduced because of substance use</td>
<td>How often do you... Give up or greatly reduce important activities now—like sports, work, or spending time with friends and family, so you can smoke?</td>
</tr>
<tr>
<td>7. The substance use is continued despite knowledge of having a persistent or recurrent physical or psychological problem that is likely to have been caused or exacerbated by the substance</td>
<td>How much does tobacco currently cause you any... Physical problems like coughing, difficulty breathing, lung trouble, or problems with your heart or blood pressure? How much does tobacco currently cause you any... Emotional problems like irritability, nervousness, restlessness, difficulty concentrating, or depression?</td>
</tr>
</tbody>
</table>

A linear, quadratic, cubic and quartic effects were included in the model. Fig. 2 presents the predicted and observed prevalence of DSM-IV nicotine dependence based on the number of cigarettes smoked in the past week. Results from polynomial contrasts showed a linear (β = 2.67, p < .001), quadratic (β = −1.36, p < .05) and cubic relationship (β = 1.03, p < .05) between quantity of use and nicotine dependence. Clearly, the prevalence of nicotine dependence is higher at higher levels of cigarette use. Nearly 35% of participants who smoked 16–25 cigarettes in the past week met criteria for nicotine dependence, while almost 60% of participants who consumed over 100 cigarettes met dependence criteria. The relationship between nicotine dependence and quantity of use showed smaller differences between 16–25 and 51–100 cigarettes smoked in the past week and subsequently larger differences again at the highest levels of use. The association between number of cigarettes smoked and nicotine dependence was similar for males and females.

3.3. Diagnostic concordance of smoking quantity

The examination of the area under the ROC curve showed an overall moderate association between past week smoking quantity and nicotine dependence in that there was an 81%...
Table 2
Prevalence of smoking and DSM-IV nicotine dependence criteria based on the week 14 survey of 859 first year college students

<table>
<thead>
<tr>
<th>Smoking in the past week</th>
<th>Total sample (n = 859)</th>
<th>Males (n = 453)</th>
<th>Females (n = 401)</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$\chi^2$(1 d.f.) = 5.3, $p &lt; 0.02$</td>
</tr>
<tr>
<td>Daily smoking in the past week</td>
<td></td>
<td></td>
<td></td>
<td>$\chi^2$(1 d.f.) = 3.3, $p &lt; 0.07$</td>
</tr>
<tr>
<td>Any DSM-IV nicotine dependence criterion met</td>
<td></td>
<td></td>
<td></td>
<td>$\chi^2$(1 d.f.) = 4.6, $p &lt; 0.03$</td>
</tr>
<tr>
<td>DSM-IV nicotine dependence diagnosis</td>
<td></td>
<td></td>
<td></td>
<td>$\chi^2$(1 d.f.) = 0.1, $p &lt; 0.78$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Past week smokers</th>
<th>Total sample (n = 176)</th>
<th>Males (n = 107)</th>
<th>Females (n = 69)</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily smoking</td>
<td></td>
<td></td>
<td></td>
<td>$\chi^2$(1 d.f.) = 0.8, $p &lt; 0.37$</td>
</tr>
<tr>
<td>Any DSM-IV nicotine dependence criterion met</td>
<td></td>
<td></td>
<td></td>
<td>$\chi^2$(1 d.f.) = 0.2, $p &lt; 0.68$</td>
</tr>
<tr>
<td>Average number of nicotine dependence criteria met</td>
<td>$M = 1.4, S.D. = 1.52$</td>
<td>$M = 1.7, S.D. = 1.91$</td>
<td>$M = 1.5, S.D. = 1.69$</td>
<td>$F = (1, 173) = 1.2, p &lt; 0.27$</td>
</tr>
<tr>
<td>DSM-IV nicotine dependence diagnosis</td>
<td></td>
<td></td>
<td></td>
<td>$\chi^2$(1 d.f.) = 0.6, $p &lt; 0.43$</td>
</tr>
</tbody>
</table>

Nicotine dependence criteria
1. Tolerance
2. Withdrawal
3. Smoking in larger amounts or longer than intended
4. Persistent desire or unsuccessful efforts to cut down
5. Great deal of time spent to obtain, use or recover
6. Activities given up or reduced
7. Smoking despite physical or psychological problems

Logistic regression analyses with polynomial contrasts were used to test the nature of the association between DSM-IV nicotine dependence and past week smoking frequency. Fig. 3 presents the prevalence of DSM-IV nicotine dependence based on the number of days smoking was reported in the preceding week. A positive linear effect was seen in the association between frequency of past week smoking and the prevalence of nicotine dependence ($\beta = 1.95, p < 0.001$). A negative quadratic effect was also found ($\beta = -1.21, p < 0.05$). The association between number of days smoked and nicotine dependence was similar for males and females.

3.5. Diagnostic concordance of smoking frequency

The examination of the area under the ROC curve again showed an overall moderate association between past week smoking frequency and DSM-IV nicotine dependence.
smoking frequency and nicotine dependence in that there was a 74% probability that a randomly selected individual with nicotine dependence would have reported smoking on more days in the past week than a randomly selected individual without nicotine dependence, AUC = 0.74 (CI 0.66–0.82).

3.6. Joint contribution of quantity and frequency in diagnosing nicotine dependence

The raw quantity and frequency indices were converted to z-scores and then combined into a quantity/frequency composite variable by summing the two standardized variables. This composite variable showed similarly moderate power in identifying nicotine dependence (AUC = 0.79), suggesting that diagnostic concordance was not enhanced by combining indices.

4. Discussion

The present study examined the association between smoking behavior and DSM-IV nicotine dependence among first year college students. Four major findings emerged. First, a positive association between smoking and nicotine dependence was supported showing higher prevalence of dependence with higher levels of use. Second, while the highest prevalence of nicotine dependence was found among those reporting the most frequent and heavy smoking, a substantial number of participants reporting daily and/or heavy smoking did not meet criteria for nicotine dependence. Conversely, nicotine dependence was seen among a subgroup of participants reporting relatively low levels of use. Finally, the associations between smoking and nicotine dependence were similar for males and females.

The positive relationship between smoking and DSM-IV nicotine dependence was observed for both quantity and frequency indices. At the lowest levels of use (i.e. fewer than 15 cigarettes or fewer than 4 days of smoking in the past week) nicotine dependence was all but nonexistent, while at the highest levels, 40–60% of participants met criteria for nicotine dependence. These results largely support previous work based on data drawn from the National Household Survey on Drug Abuse (NHSDA). First, the positive association between level of use and prevalence of dependence has been separately shown for smoking (Kandel and Chen, 2000), marijuana (Chen et al., 1997) and cocaine (Chen and Kandel, 2002). Overall, smoking behavior and nicotine dependence observed in the present sample were similar to those reported among adolescents from the NHSDA. In that sample, dependence was reported among 28% of adolescent smokers, compared to our prevalence of 26%. Further, within both samples, the large majority of smokers were found to smoke less than a pack a day on average (Kandel and Chen, 2000).

The present examination of the area under the receiver operator characteristic curve (AUC) is, to our knowledge, the first attempt to estimate the overall diagnostic concordance of smoking indices and DSM-IV nicotine dependence. While information on smoking quantity and frequency afforded detection of nicotine dependence well above chance levels, overall diagnostic concordance was moderate and did not improve when quantity and frequency information was combined. Given the lack of an error-free “gold standard” for nicotine dependence, however, the AUC estimates should be interpreted with some caution as these parameters may be found to differ as we move from populations of low to high prevalence (Buck and Gart, 1966).

Taken together, the results presented here have important theoretical implications for understanding the link between smoking and dependence. On the one hand, a marked prevalence of dependence was seen at low levels of use including both non-daily smoking and smoking no more than a pack of cigarettes in the past week. On the other, even at the highest levels of use, only about half of the sample was indeed positive for nicotine dependence. In fact, fewer than half of the nicotine dependent cases smoked daily and only 10% smoked more than five packs in the past week. Aside from demonstrating the lack of a one-to-one relationship between smoking and nicotine dependence, these seemingly divergent findings have previously been interpreted as an indication of different sensitivities to nicotine exposure across individuals (DiFranza et al., 2000). For example, Kandel and Chen (2000) showed that adolescents smoke fewer cigarettes than adults, but experience a higher prevalence of dependence at the same levels of use. Future research is needed to determine physiological and psychological differences within adolescents that may provide clues regarding sensitivity to nicotine.

Given that previous work has suggested gender differences in smoking quantity (Stanton, 1995), prevalence of nicotine dependence, as well as their association (Kandel and Chen, 2000), the lack of gender differences found in the present study was unexpected. However, college smoking appears to be equally popular among young men and women, and previous research focused exclusively on college samples have shown fewer gender differences (Everett et al., 1999; Rigotti et al., 2000). Results from the National College Health Risk Behavior Survey showed that among students who had ever tried smoking (70%), women were as likely as men to report being current smokers, current frequent smokers, current daily smokers, as well as ever-daily smokers (Everett et al., 1999). In the present study, while females were less likely to report smoking in the past week and to meet one or more nicotine dependence criterion, they showed statistically similar prevalence of smoking and nicotine dependence. Further, the patterns of association between smoking and nicotine dependence did not differ by gender.

The current results should be interpreted within the context of study limitations. First, the time frames used to capture both smoking behavior (i.e. past week) and experiences of nicotine dependence (i.e. past month), while unlikely to have affected the overall patterns of observed relationships, may affect the specific cut points which maximize the correct classification of dependent and nondependent cases. One previous study to have examined prevalence of nicotine dependence by smoking level evaluated assessments of smoking behavior in the past month as a predictor for having met nicotine dependence criteria in the past year (Kandel and Chen, 2000). While different proportions of dependence at various levels of use between these studies may have been driven in large part by the wide age range and heavier levels of smoking reported in the larger NHSDU sample, the role of assessment periods should also be carefully considered...
in the development of future research. That is, although assessment of dependence symptoms across a continuum of smoking levels is critical for establishing their relationship, the optimal assessment periods for evaluating these constructs remain unclear. When shorter periods are used for evaluating symptoms of dependence, there is a risk of underestimation in cases where smoking behavior may be heavy and regular with few opportunities for symptoms of withdrawal or further increases in tolerance. In contrast, longer periods may call into question the extent to which the smoking behavior and reported dependence symptoms are truly concurrent.

Given that DSM-IV nicotine dependence refers to a list of criteria and does not explicitly propose questions meant to measure corresponding experiences, to the degree that individual questions in any assessment may not fully tap these criteria, there remains the possibility of some discrepancies between DSM and its measurement. By virtue of excluding the daily smoking criterion which has traditionally been considered a necessary aspect of dependence, our prevalence will likely be higher than those found in studies that include daily smoking in the dependence algorithm. Further, in that the present study examined a largely Caucasian sample of college students, future work will be required to inform the relationship between smoking and DSM-IV nicotine dependence across diverse samples.

Further, our findings are directly tied to the measurement of nicotine dependence according to DSM-IV, a conceptualization, which was developed based on adult substance use patterns. While it has been argued that nicotine dependence among adolescent smokers is best measured by those assessments developed for young emergent smokers, there is little corresponding empirical work to support this (Colby et al., 2000a, b). Notably, in a separate paper based on the present sample, the TTURC nicotine dependence inventory (NDI) was found to predict future smoking behavior similarly and in some cases, better than the HONC which was developed to detect the emergence of nicotine dependence symptoms among young adolescents. That is, while both the HONC and NDI predicted continued smoking at the 5-month follow-up, only the NDI measure continued to predict smoking at 15 months once initial smoking quantity and frequency was controlled (Sledjeski et al., 2006). These findings may of course be driven by the fact that the present sample was transitioning to young adulthood. Nevertheless, they highlight the suitability of NDI assessment in this sample.

It should also be noted that while our assessment focused on daily smoking, it was based exclusively on self-report requiring retrospective recall of past week behavior without biochemical verification. While some questions have been raised regarding the accuracy of self-reported smoking, the advantages of using self-monitoring techniques are commonly believed to outweigh the disadvantages (Patrick et al., 1994; Stanton et al., 1996). For example, reports of number of cigarettes smoked per day have been shown to be a valuable index of smoking heaviness, being positively correlated with level of CO, cotinine and nicotine in group data (Heatherton et al., 1989). Further, restricting recall to the past week, rather than several weeks or even lifetime use likely maximized accuracy. Self-reported quantity, however, may not adequately quantify actual nicotine exposure given individual variability in smoking topography (Wood et al., 2004). Our measure of total weekly consumption also did not operationalize duration of smoking or tap different patterns of smoking throughout the day (e.g. binge experiences). The relationship between smoking and dependence may differ based on these more intricate patterns of use and this represents an important area of inquiry.

In general, these results suggest that level of cigarette consumption among young adults is moderately tied to the expression of nicotine dependence. Nicotine is typically viewed as the primary cause of tobacco use and dependence, and nicotine exposure is determined, primarily, by inhalation of tobacco smoke (Benowitz, 2001). The modest association between cigarette consumption and nicotine dependence is not surprising in light of the fact that nicotine levels achieved through smoking are not precisely determined by the frequency or quantity of cigarette use (Benowitz, 2001). Studies of smoking topography (which is comprised of variables such as maximum puff velocity, puff volume, and number of puffs) reveal that smokers vary considerably in the amount of smoke they inhale when they smoke a cigarette (USDHHS, 1988; Kozlowski et al., 2001). Consequently, the number of cigarettes smoked over a given period is not strongly related to total nicotine exposure for that same period.

Given the cross-sectional nature of our data, it is also important to note that the present findings do not inform the use/dependence link related to the emergence of dependence. That is, when examining smoking history among participants who reported nicotine dependence at relatively low levels of use, more than half reported smoking at higher levels in the past suggesting that their dependence may in fact have been established at higher levels of use. Notably, groundbreaking work on the emergence of dependence symptoms among novice adolescent smokers has supported the emergence of nicotine dependence well before the onset of daily smoking for a substantial subset of the population (DiFranza et al., 2000; Karp et al., 2005).

A further complication in examining the association between smoking exposure and dependence is the statistical assumption that the direction of causality only flows in one direction (i.e. smoking increases risk of dependence symptoms). Instead smoking behavior may be a consequence of nicotine dependence either: (1) rather than a cause, or (2) in addition to being a cause. As has been reviewed by previous authors (e.g. Duncan et al., 2004), this endogenous relationship creates the potential for bias in parameter estimates. Thus, the present findings should be interpreted in terms of the prominent patterns, that is, that substantial individual variability exists, as seen by the presence of nicotine dependence at low levels of smoking and the modest prevalence of dependence at the highest levels of smoking.

Finally, our examination of the smoking/nicotine dependence relationship did not take into consideration either, the nested structures within the data (e.g. students nested within dorm rooms, nested within dormitories) in which the inclusion of more than one participant may result in non-independent observations, nor the possibility of behavioral contagion among study participants. Recent evidence has shown that school environments are vulnerable to peer contagion (Dishion and Dodge, 2005) and...
while dorms at the state university sampled in the present study were officially smoke-free, it is likely that smoking behavior was correlated between roommates and/or within dorm floors or dormitories.

Despite study limitations, the present investigation has some practical implications that may guide future research. First, in the absence of nicotine dependence assessment, research has routinely used measures of intensity of use based on quantity and/or frequency indices as an indicator of serious substance involvement (e.g. Dierker et al., 2004). While this study confirms that smoking indices provide a reasonable proxy for DSM-IV nicotine dependence, fewer than half of the participants at any given level of use were dependent on nicotine. That is, high levels of use will assure the highest prevalence of nicotine dependence, but bring with them high proportions of false positives (i.e. high level smokers who are not nicotine dependent).

More importantly, the present findings may be used to inform a screening measure for studies that require dependent smokers for further study or intervention purposes. While selecting daily smokers has been the traditional approach, our findings suggest that many dependent cases will be missed at these high levels, and that nicotine dependence will not be adequately represented across the continuum of use. Further, given that most smoking interventions target the prevention of the first smoking experiences (Lantz et al., 2000) or the treatment of heavily dependent, chronic smokers (e.g. Fiore, 2000), the present findings suggest needed attention to smokers past the earliest exposures, but before daily smoking patterns are formed. Currently, the malleability of smoking behavior during this uptake process is unknown, but may represent appropriate timing for indicated intervention programming (IOM, 1996; Fiore, 2000; Okuyemi et al., 2002).

The major strength of our study was the assessment of nicotine dependence among all past week smokers allowing for an examination of nicotine dependence across a continuum of smoking behavior. Past research has shown that approximately 70% of all people try a cigarette sometime during their life (SAMHSA, 2002), yet only a third of those who reach daily smoking levels continue smoking to the point of dependence (Breslau et al., 2001). Currently, little is known about differences between those who progress to dependence and those who engage in smoking but do not make this transition. While chronic use may be a key feature, the present study has shown substantial individual variability in concurrent smoking levels and the presence of nicotine dependence. Future work is needed to determine the individual differences that may provide clues regarding differential sensitivities to nicotine. Overall, it is clear that dependence is not fully isomorphic with smoking, and that the expression of dependence can vary considerably across individuals even with comparable exposure to smoking (Colby et al., 2000a,b; Kandel and Chen, 2000).

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References


