Predictors of nicotine dependence symptoms among never-smoking adolescents: A longitudinal analysis from the Nicotine Dependence in Teens Study

Simon Racicot^a, Jennifer J. McGrath^a, Igor Karp^{b,c}, and Jennifer O'Loughlin^{b,c,d,*}

^aPediatric Public Health Psychology Laboratory, Department of Psychology, Concordia University, 7141 Sherbrooke Street West, Montréal, Québec, Canada H4B 1R6

^bDepartment of Social and Preventive Medicine, University of Montréal, 1430 Mont-Royal Blvd., Montréal, Québec, Canada H2V 4P3

^cCentre de recherche du Centre Hospitalier de l'Université de Montréal (CHUM), 3850 Saint-Urbain Street, Montréal, Québec, Canada H2W 1T7

^dInstitut national de santé publique du Québec, 190 Crémazie Blvd. East, Montréal, Québec, Canada H2P 1E2

Abstract

Background—Recent cross-sectional studies suggest some adolescents who have never smoked cigarettes experience nicotine dependence (ND) symptoms and that exposure to second-hand smoke, social exposure to smoking, and alcohol use are plausible correlates. The aim of this study was to replicate and extend these findings by investigating possible predictors of ND symptoms longitudinally.

Method—Participants included 847 secondary school students who had never smoked cigarettes enrolled in the Nicotine Dependence in Teens Study. Adolescents completed self-report questionnaires measuring smoking status, ND symptoms, and risk factors for ND in smokers (i.e., socio-demographic indicators, social exposure to smoking, psychosocial indicators, and substance use) in 20 survey cycles from 7 to 11th grade. Generalized estimating equations, which account for repeated measures within individuals, were used to test the predictors of ND symptoms.

Results—Consistent with previous research, 7.8% of never-smokers across all cycles endorsed at least one ND symptom. Younger age ($p < .001$), country of birth ($p < .05$), peer smoking ($p < .001$), teacher smoking ($p < .05$), depression ($p < .05$), stress ($p < .001$), lower self-esteem ($p < .05$),

*Corresponding author at: Pediatric Public Health Psychology Laboratory, Department of Psychology, Concordia University (Loyola Campus), 7141 Sherbrooke Street West, Montréal, Québec, Canada H4B 1R6. Tel.: +1 514 848 2424x5207. jennifer.mcgrath@concordia.ca (J.J. McGrath).

Contributors

Simon Racicot developed the research question, conducted the literature review, undertook the statistical analyses, interpreted the results, and wrote and revised the manuscript. Jennifer J. McGrath supervised the literature review, the statistical analyses, and revised the manuscript. Igor Karp designed the analytical plan and revised the manuscript. Jennifer O'Loughlin designed the study, contributed to the protocol development, and revised the manuscript. All authors read and approved the final manuscript for submission.

Conflict of interest

There is no conflict of interest.

impulsivity ($p = .05$), and alcohol use ($p = .001$) predicted greater ND symptoms in multivariable modeling.

Conclusions—Replicating previous cross-sectional findings, peer smoking and alcohol use predicted ND symptoms among never-smoking adolescents. Extending these findings, previous predictors only observed among ever-smokers, including socio-demographic and psychosocial indicators, also predicted ND symptoms. This longitudinal investigation demonstrated the temporal relation of the predictors preceding ND symptoms. Future research should consider longer prospective studies with younger children to capture early onset of ND symptoms and with longer follow-up to detect eventual smoking uptake.

Keywords

Smoking; Nicotine; Adolescent; Tobacco use disorder; Risk factors; Cohort studies

1. Introduction

Nicotine dependence (ND) is defined by symptoms of withdrawal, tolerance, and difficulty controlling tobacco use during a 12-month period (American Psychiatric Association, 2000). According to this clinical conceptualization, daily smoking is a requisite criterion for its diagnosis. However, this notion has been challenged by research suggesting that ND can be reported not only soon after smoking initiation, but also before initiation. The aim of the present study was to identify predictors of ND symptoms in a longitudinal sample of adolescent never-smokers.

Early reports of ND symptoms have been observed among ever-smokers. DiFranza et al. (2000) found that 22% of adolescents experienced ND symptoms within the first month following consumption of at least one cigarette, with 6% reporting at least one symptom in the first two weeks. Surprisingly, a small percentage of never-smokers endorsed “really needing a cigarette” (2.5%) and “having strong cravings to smoke” (1.7%). Following smoking initiation (0 mos), 20% of adolescent smokers reported mental addiction (2.5 mos), cravings (4.5 mos), physical addiction (5.4 mos), withdrawal symptoms (11.0 mos) and tolerance (13.0 mos), well before the onset of weekly smoking (19.4 mos) and the development of ICD-10 dependence (40.6 mos; Gervais et al., 2006). Such findings provide convincing evidence that ND symptoms can be reported early in the course of smoking. Subsequent research examined risk factors during adolescence associated with early reports of ND among smokers.

1.1. Predictors of ND symptoms during adolescence in smoking populations

Social exposure to smoking by significant others during adolescence is associated not only with smoking behavior (O’Loughlin et al., 2009), but also with ND. Parental smoking (Brook et al., 2009; Kleinjan et al., 2012) and parental ND (Hu et al., 2011) during adolescence were found to predict ND in adolescent and adult smokers. Further, sibling smoking and peer smoking predicted ND in adolescent smokers (Audrain-McGovern et al., 2007; De Leeuw et al., 2009; Hu et al., 2011; Wileyto et al., 2009).

Psychosocial indicators have also been identified as risk factors for ND among smoking adolescents. Depressed mood and novelty-seeking predicted ICD-10 ND and loss of autonomy over tobacco use (DiFranza et al., 2007; Karp et al., 2006). Moreover, externalizing behavior problems (Hu et al., 2011; Storr, 2008) have been identified as risk factors, whereas impulsiveness was inversely associated with ICD-10 ND (DiFranza et al., 2007). With respect to substance use, alcohol has been found to predict ND among smoking adolescents (Storr, 2008; Wileyto et al., 2009).

In addition to identifying risk factors for ND, growth-modeling studies demonstrate that ND emerges through longitudinal trajectories during adolescence (Hu et al., 2008; Kleinjan et al., 2010, 2012). Trajectories are based on distinct profiles (e.g., severity, timing, symptoms). Factors predicting trajectory membership include conduct disorder, parental ND, novelty-seeking (Hu et al., 2008), parental and peer smoking, and depression (Kleinjan et al., 2010). Taken together, social exposure to smoking, psychosocial risk factors, and substance use have been found to predict ND and trajectory membership in adolescent smokers.

1.2. ND symptoms during adolescence in tobacco-naïve populations

Extant literature demonstrates ND symptoms can be reported not only by smokers, but also by never-smokers. It is plausible that second-hand smoke exposure (SHS) explains this unexpected and intriguing observation. Prokhorov et al. (2005) found that the prevalence of 5 of 7 withdrawal symptoms was similar in never- and former smokers. Bélanger et al. (2008) reported 4.6% of never-smoking 5th graders endorsed at least one ND symptom, and SHS exposure in cars (*Hedges g* = .09), sibling smoking (*g* = .14), and peer smoking (*g* = .10) were associated with ND symptoms; parental smoking was not associated (*g* = .06). Racicot et al. (2011a,b) found that the number of smokers among parents, siblings, and peers (*g* = .16) predicted ND symptoms in adolescent never-smokers. Moreover, Racicot et al. (2011a,b) found 6.2% of never-smokers endorsed at least one ND symptom at baseline. Alcohol use (*g* = .11) and peer smoking (*g* = .07) were associated with ND symptoms; parental (*g* = .02) and sibling smoking (*g* = .02) were not associated. Relatedly, never-smoking adolescents reporting ND symptoms have an increased likelihood of smoking susceptibility (Okoli et al., 2009) and smoking initiation (O'Loughlin et al., 2009). Taken together, there is emerging evidence that never-smokers endorse ND symptoms, that smoke exposure itself predicts which never-smokers will endorse these symptoms, and that ND symptoms are a risk factor for eventual initiation.

To date, cross-sectional data indicate ND has been observed in never-smoking populations, and social exposure to smoking and substance use are correlates of ND symptoms. Given that ND predicts smoking susceptibility and initiation, identifying predictors of ND symptoms among never-smokers warrants further investigation. The current objective was to identify predictors of ND symptoms in a school-based, longitudinal sample of adolescents who had never smoked. Potential predictors were selected based on previously demonstrated associations with ND in adolescent smokers and included socio-demographic indicators, social exposure to smoking, psychosocial indicators, and substance use.

2. Method

2.1. Procedure and participants

Nicotine Dependence in Teens (NDIT) is a longitudinal cohort of 1293 7th grade students, aged 12–13 years at baseline, designed to investigate the onset and development of cigarette smoking and ND. Students were recruited in a convenience sample of 10 public schools in Montréal (Québec, Canada) selected in partnership with school boards and principals. To maximize representativeness, schools were purposely selected from urban, suburban, and rural settings, as well as low, moderate, and high socioeconomic districts. Data were collected in 20 survey cycles from 1999 to 2005 (4 per school year from grade 7 to 11). Self-report questionnaires were administered at school in the language of instruction (i.e., English or French). All participants provided assent; informed parental consent was obtained in signed consent forms. NDIT received ethics approval from the *Centre de recherche du CHUM* (#ND06.087).

2.2. Measures

2.2.1. Smoking status—Smoking status was assessed at each survey cycle using two items: “Have you ever in your life smoked a cigarette, even just a few puffs?” (*No* to *Yes, more than 10 times*) and “Check the one box that describes you best...” (*I have never smoked a cigarette, even just a few puffs* to *I smoke cigarettes every day*). Never-smoking was defined conservatively as having never smoked a cigarette, not even a few puffs.

2.2.2. ND symptoms—ND symptoms were assessed with items adapted from an ND/craving symptom indicator (O’Loughlin et al., 2002a). Adolescents rated four items on a 4-point scale: “When you see other kids your age smoking cigarettes, how easy is it for you not to smoke?” (*Very easy* to *Very difficult*); “How often have you felt like you really need a cigarette?” (*Never* to *Often*); “How physically addicted to smoking cigarettes are you?” (*Not at all* to *Very*); and “How mentally addicted to smoking cigarettes are you?” (*Not at all* to *Very*). The original ND/craving symptom indicator was based on a sample of smoking adolescents and evidenced excellent internal reliability (Cronbach’s $\alpha = .94$), test-retest reliability (ICC = .91), and convergent validity with the Hooked on Nicotine Checklist ($r = .91$) and ICD-10 ($r = .82$). The adapted items were those four answered by never-smokers; principal components analysis revealed the original component structure was retained (i.e., all items loaded on one component; all loadings $> .6$). Consistent with previous scoring schemes (Bélanger et al., 2008; Racicot et al., 2011a,b), items were summed to yield a composite score (range 0–12). Prevalence data are estimated for those who endorse at least one ND symptom (i.e., non-zero score).

2.2.3. Socio-demographics—Socio-demographic data included age, sex, language spoken at home, country of birth, parental education, and perceived family income.

2.2.4. Social exposure to smoking

2.2.4.1. Adult smoking: Adolescents indicated whether adults residing in their household smoked cigarettes, based on a list of 10 family members (e.g., mother, father, aunt). The response categories were summed to yield the total number of smoking adults (range 0–10).

2.2.4.2. Sibling smoking: Adolescents reported how many siblings, including step-or half-siblings, smoked. The response categories were summed to yield the total number of smoking siblings.

2.2.4.3. Peer smoking: Adolescents answered, “How many of the friends whom you usually hang out with smoke cigarettes?” using a 5-point scale (*None* to *Most or all*).

2.2.4.4. Schoolmate and school personnel smoking: Adolescents answered, “I see students smoke near the school” using a 3-point scale (*Not at all true* to *Very true*). A second question was asked about teachers/school staff.

2.2.5. Psychosocial indicators

2.2.5.1. Depression: Depression was measured with the six-item Mellinger Depressive Symptoms Scale (Kandel & Davies, 1982). Adolescents rated items over the past 3 months using a 4-point scale (*Never* to *Often*). Items are summed to create a total score (range 0–18); higher scores indicate greater depression. This measure evidences good internal consistency ($\alpha = .89$, Chaiton et al., 2010; $\alpha = .85$, present study).

2.2.5.2. Stress: Stress was measured using a list of stressful life events typically encountered during adolescence (e.g., breaking up with girlfriend, parental divorce; Deschenes, 1997). Adolescents rated whether they were worried or stressed about 15 items over the past 3 months on a 4-point scale (*Not at all* to *A whole lot*). Items are summed to create a total score (range 0–45); higher scores indicate greater stress. This scale has good internal consistency ($\alpha = .83$ – $.89$, Deschenes, 1997; $\alpha = .79$, present study).

2.2.5.3. Perceived academic performance: Adolescents rated their academic performance in response to the question, “I’m not doing well at school” on a 3-point scale (*Not at all true* to *Very true*).

2.2.5.4. Self-esteem: Self-esteem was measured using Rosenberg’s Self-Esteem Scale (1965; Vallières & Vallerand, 1990). Adolescents rated nine items over the past 3 months on a 3-point scale (*Not at all true* to *Very true*). Items are summed to create a total score (range 0–18); higher scores indicate higher self-esteem. This scale displays good test-retest reliability ($r = .84$) and internal consistency ($\alpha = .88$, Vallières & Vallerand, 1990; $\alpha = .80$, present study).

2.2.5.5. Novelty-seeking: Novelty-seeking was assessed using nine items based on Cloninger’s Tridimensional Personality Questionnaire (e.g., “When nothing new is happening, I usually start looking for something that is exciting”; Cloninger, 1987) rated on a 5-point scale (*Not at all true* to *Very true*). Items are summed to yield a total score (range 0–36); higher scores indicate greater novelty-seeking. This scale has good internal consistency ($\alpha = .77$, Wills et al., 1998; $\alpha = .81$, present study).

2.2.5.6. Impulsivity: Impulsivity was assessed with an abbreviated version of the Eysenck Impulsivity Scale (Eysenck and Eysenck, 1977), which has been previously validated with adolescents (Wills et al., 1998). Adolescents rated seven items on a 5-point scale (*Not at all*

true to *Very true*). Items are summed to yield a total score (range 0–28); higher scores indicate greater impulsivity. This measure evidences good internal consistency ($\alpha = .87$, Wills et al., 1998; $\alpha = .87$, present study).

2.2.6. Substance use—Frequency of other tobacco products and alcohol use in the past three months was assessed separately with two items (“smoke cigar or cigarillo”, “drink beer, wine or hard liquor”) using a 5-point scale (*Never* to *Usually every day*).

2.3. Data analysis

The initial sample was comprised of never-smokers at cycle 1. At each subsequent survey cycle, smoking status was ascertained to verify whether participants still met the never-smoking inclusion criterion. Participants were excluded at the given cycle that they reported ever-smoking and every cycle thereafter. For example, a participant reporting smoking for the first time at cycle 5 would be included from cycles 1–4, but excluded from cycles 5–20. Participants whose smoking status was unknown at any follow-up cycle were similarly excluded. This conservative criterion was used to ensure the sample was exclusively never-smokers.

Given the design of NDIT, some questions were asked at every cycle, while others were measured less frequently (detailed study design provided in O’Loughlin et al., 2009). Missing values on questions that were asked once or 2–3 times were substituted in two steps. First, for questions measured only once, the same value was imputed for all cycles. For variables measured 2–3 times, the value from the last available observation was carried backwards. Second, multiple imputation was used for all the remaining missing observations, which included missing values on questions asked at each cycle, questions asked once or 2–3 times, and cycles that had been skipped. Missing values were imputed 20 times in Amelia II (Honaker et al., 2012).

Generalized estimating equations (GEE), with the independent correlation structure, were employed to account for repeated measures within participants. Given that ND symptoms were coded as a continuous score, analyses were conducted with linear regression modeling. Using an analytic strategy similar to that in earlier NDIT analyses (O’Loughlin et al., 2009), potential predictors at each cycle were used to predict ND symptoms at the subsequent cycle (i.e., T1 variables to predict ND at T2, etc.). This approach was utilized so predictors closest in time (3–4 months prior) would predict ND symptoms. Data for all participants and cycles were pooled, in accordance with the pooling of repeated observations method (e.g., Cupples et al., 1988; D’Agostino et al., 1990; Karp et al., 2004).

Univariate and multivariable regression analyses were conducted separately for each potential predictor to evaluate its association with ND symptoms at the next cycle. All multivariable analyses were age- and sex-adjusted; additional covariates were included in the model if the correlation coefficient between the covariate and the potential predictor was $\geq .20$ (Hosmer and Lemeshow, 2000). Unstandardized beta coefficients, which are less affected by arbitrary features of the study design and population (Greenland et al., 1986), were derived with their estimates of standard error and the corresponding Wald χ^2 test statistic.

3. Results

3.1. Descriptive statistics

Among the entire NDIT cohort, adolescents participated in 16.3 survey cycles ($SD = 5.91$). Of these, 847 participants were never-smokers at baseline (Table 1). Compared to ever-smokers ($n = 446$; $M_{age} = 12.99$ years, $SD = .73$), never-smokers were younger, $t = 9.59$, $p < .001$, more likely to be born outside Canada, $\chi^2 = 6.76$, $p < .01$, attended an English-language school, $\chi^2 = 75.88$, $p < .001$, and spoke English at home, $\chi^2 = 104.34$, $p < .001$. There were no sex differences, $\chi^2 = 3.04$, $p = .08$. A total of 405 participants reported ever smoking and were excluded at that corresponding cycle. The prevalence of reporting at least one ND symptom among never-smokers, across all cycles, was 7.88% ($SD = 1.98$; range 4.8–13.0%). The attrition rate did not differ between never-smokers and ever-smokers, 25% over 20 cycles; $t = 1.13$, $p = .81$.

3.2. Predictors of ND symptoms

Univariate and multivariable regression models are presented in Table 2. In multivariable modeling, among the socio-demographic variables, younger age and being born in Canada were associated with greater ND symptoms, while controlling for covariates. Other socio-demographic variables including sex, language spoken at home, family income, and parental education were not associated in the multivariable models. Among the social smoke exposure indicators, observing peer and teacher smoking were associated with greater ND symptoms, after controlling for covariates. Living with adult smokers, having siblings who smoke, and being exposed to schoolmate smoking were not associated in the multivariable models. Among the psychosocial indicators, higher self-reported depression, stress, and impulsivity, as well as lower self-esteem were associated with greater ND symptoms, while controlling for covariates. Novelty-seeking and perceived academic performance were not associated in the multivariable models. Finally, among the substance use indicators, more frequent alcohol use was associated with greater ND symptoms, while controlling for covariates; cigar/cigarillo use was not associated.

4. Discussion

Accumulating evidence suggests ND symptoms can occur soon after smoking initiation (e.g., DiFranza et al., 2007; Gervais et al., 2006). Intriguingly, cross-sectional studies evidence that 4–6% of never-smoking adolescents endorse items measuring ND (e.g., Bélanger et al., 2008; Racicot et al., 2011a,b). The objective of this study was to corroborate and extend previous cross-sectional findings by identifying predictors of ND symptoms longitudinally among adolescents who had never smoked a cigarette, not even a few puffs. In the present study, the prevalence of never-smokers endorsing ND symptoms (7.8%) was similar to past reports. Consistent with findings in adolescent smokers (e.g., Audrain-McGovern et al., 2007; De Leeuw et al., 2009; Hu et al., 2011), socio-demographic indicators, social exposure to smoking, psychosocial indicators, and substance use predicted ND symptoms in never-smokers.

Age and country of birth were the socio-demographic indicators associated with ND symptoms. Age was inversely associated to ND. Higher ND symptoms were observed in the early survey cycles when adolescents were younger. Relatedly, adolescents who were more likely to endorse ND symptoms commenced smoking earlier, and consequently, were excluded at a younger age. This phenomenon is referred to as the “depletion of susceptibles” (Garbe & Suissa, 2005; Karp et al., 2006) whereby in a longitudinal cohort of adolescent never-smokers, those who initiate smoking are excluded from the sample. Among participants who began smoking during follow-up, a higher proportion was censored in earlier survey cycles compared to later cycles. Of note, the prevalence of adolescents who tried smoking is consistent with national estimates of smoking initiation among youth attending 10–12th grades (47.8% vs. 48.2%, respectively; Health Canada, 2008). Previous research has demonstrated that ND symptoms predict smoking uptake in adolescents (O’Loughlin et al., 2009). Further, attrition does not account for the observed age finding; never- and ever-smokers in the entire NDIT cohort were followed for the same number of survey cycles. The other socio-demographic indicator, country of birth, was also associated. Foreign-born participants obtained lower ND symptoms scores, regardless of language spoken at home. It is possible that Canadian-born participants were raised in a more “pro-smoking” culture.

Social exposure to smoking is a risk factor for ND symptoms in adolescents (e.g., Bélanger et al., 2008; Brook et al., 2009; De Leeuw et al., 2009). Current findings corroborated this association as smoking by friends ($g = .19$) predicted ND symptoms. Parental ($g = .03$) and sibling ($g = .01$) smoking were not associated. This result is consistent with previous studies showing that the relative influence of family members and friends varies by age, with family members having a greater influence in childhood and friends having a greater influence in adolescence (e.g., Vitaro et al., 2004). Social contagion theory (Rowe et al., 1992) may explain the observation that never-smokers come to believe that they (should) experience cravings when friends talk openly about their cravings. To our knowledge, smoking by school personnel has never been evaluated as a risk factor for ND among never-smokers. Implementing and enforcing smoke-free policies in schools should be emphasized as a strategy to prevent the development of risk factors for smoking initiation (Barnett et al., 2007).

Among psychosocial indicators, depression, stress, self-esteem, and impulsivity predicted ND symptoms. Affect control, boredom reduction, and greater social benefits are consequences that never-smoking adolescents expect from smoking cigarettes (Hine et al., 2007). Negative affect may predispose adolescents to perceive ND symptoms and expect smoking will help curb unpleasant emotions. Foster et al. (2012) found never-smoking adolescents with clinical levels of impulsivity were more likely to believe smoking controls affect and reduces boredom. These adolescents are at increased risk of initiating smoking. In adolescent smokers, smoking expectancies have been found to predict eventual ND (Heinz et al., 2010).

When examining psychoactive substances other than cigarettes, alcohol consumption predicted ND symptoms ($g = .12$), which coincides with past findings (Racicot et al., 2011a,b). This association was probable, given that smoking and alcohol use frequently co-

occur (Jackson et al., 2000). Alcohol use confers greater risk for ND in recent onset adolescent smokers (Dierker et al., 2011). Relatedly, alcohol use has been found to increase tolerance to nicotine in mice (Collins et al., 1988).

4.1. Limitations

There were three limitations of the current study. First, data were self-reported. Although misclassification is possible, self-report is systematically used to measure adolescent smoking behavior and it is reliable (Eppel et al., 2006). Future studies should use biomarkers to cross-validate smoking status. Second, schools were selected via convenience sampling, which may limit the generalizability of the results. However, school selection was stratified by population density (i.e., rural, suburban, urban) and socioeconomic status (i.e., low, medium, high), as reported by school boards, to maximize external validity. Third, the non-experimental design of NDIT makes causal inference challenging; however, using prospective data permitted the evaluation of temporal relationships between ND symptoms and potential predictors.

4.2. Strengths

Strengths of this study also merit consideration. First, the analytical sample ($N = 847$) included a large number of adolescents recruited in secondary schools. Given that adolescence is the developmental stage when individuals are most likely to experiment with tobacco (Chassin et al., 2000), this period was optimal for evaluating risk factors for ND. Second, the measurement definitions of ND and never-smoking status were rigorous. Items measuring ND have been shown to possess strong psychometric properties (O'Loughlin et al., 2002a). Never-smoking status was defined conservatively to ensure that participants had never smoked cigarettes, not even a puff. Third, ND predictors were derived from validated, standardized scales, which facilitates comparisons across studies. The wide range of predictors were classified into four categories and investigated to depict a multifaceted analysis of ND symptoms.

4.3. Conclusions

The unexpected phenomenon of ND symptoms among never-smokers has been repeatedly observed (cf., Bélanger et al., 2008; DiFranza et al., 2000; Okoli et al., 2009; O'Loughlin et al., 2009; Prokhorov et al., 2005; Racicot et al., 2011a,b). This longitudinal study replicated previous cross-sectional findings, as peer smoking and alcohol use predicted ND symptoms among never-smoking adolescents. Extending these findings, additional predictors of ND, previously only observed among ever-smokers, were identified including socio-demographic indicators (i.e., age, country of birth) and psychosocial indicators (i.e., depression, stress, self-esteem, impulsivity). Further, this longitudinal investigation established temporality of exposure whereby indicators preceded endorsement of ND symptoms at subsequent time-points. These findings contribute new knowledge regarding the emergence of ND symptoms in never-smoking adolescents. The question remains whether adolescents correctly understand the content of these items; however, qualitative work suggests that adolescents conceptually distinguish physical addiction ("like an empty spot in the chest") from mental addiction ("I think I can only feel it in my head"; O'Loughlin et al., 2002b, p. 205). Further psychometric development of the assessment of ND symptoms in young never-smokers

should consider whether individual items are differentially weighted, using an item-response theory framework (e.g., MacPherson et al., 2008), across childhood and adolescence.

Converging evidence with animal data provide additional support for the hypothesis that active smoking is not required to experience ND symptoms and suggest neuroadaptations account for somatic withdrawal effects observed in nicotine-naïve rats exposed to SHS (Yamada et al., 2010). Based on the Sensitization-Homeostasis model (DiFranza and Wellman, 2005), nicotine exposure through SHS could prime the addiction pathway and lead to experiencing ND symptoms (Bélanger et al., 2008). Recent findings support this notion of pharmacological priming. Brody et al. (2011) showed that SHS exposure leads to $\alpha 4\beta 2^*$ nicotinic cholinergic receptor occupancy in non-smokers, which parallels findings of withdrawal sensations observed in tobacco-naïve rats exposed to SHS (Small et al., 2010). Relatedly, it is unclear whether pharmacological exposure to nicotine may partly explain established findings with social modeling. Biomarkers of nicotine and SHS exposure could be used to empirically evaluate pharmacological priming as a predictor of ND symptoms.

Future research should investigate why some participants reporting ND symptoms convert to smoking, whereas others may be resilient to smoking uptake despite endorsing ND symptoms. Longer prospective studies are strongly recommended to capture both early endorsement of ND symptoms and late smoking onset. In the present sample, 30% who converted to ever-smoking status started smoking within the first three cycles. While the current longitudinal study started in 7th grade, it may be prudent to begin investigating the emergence of ND symptoms in elementary school. Some adolescents may endorse ND symptoms and resist smoking uptake due to protective factors (e.g., extracurricular activities, good relationship with parents; DiFranza et al., 2007), genetic differences in nicotine metabolism (Malayandi et al., 2005), or possibly perceived risk of SHS exposure (Song et al., 2009). Previous research has suggested there may be a class of “late bloomers” who endorse ND symptoms, but take a longer period of time before trying smoking (Karp et al., 2005). Thus, follow-up periods extending into young adulthood may be warranted to accurately detect eventual smoking uptake. Prospective studies including additional covariates and employing other analytic strategies (e.g., latent growth curve modeling) could help further address this question. Prevention programming should consider ND a novel predictor for adolescent smoking behavior, given that ND predicts smoking susceptibility (Okoli et al., 2009) and smoking initiation (O’Loughlin et al., 2009).

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Table 1

Descriptive statistics of ND symptom predictors at survey cycles 1, 10, and 19.

Predictor	Cycle 1 <i>M</i> (SD) or % <i>N</i> = 847	Cycle 10 <i>M</i> (SD) or % <i>N</i> = 476	Cycle 19 <i>M</i> (SD) or % <i>N</i> = 325
<i>Socio-demographics</i>			
Age (years)	12.7 (.5)	14.8 (.4)	17.0 (.4)
Female sex (%)	49.8%	46.6%	46.5%
Language spoken at home (%)			
English	58.2%	59.2%	58.8%
French	22.4%	21.6%	20.3%
English and French	10.4%	9.0%	9.2%
Other	9.0%	10.1%	11.7%
Born in Canada (%)	91.0%	92.0%	91.7%
Family income (% better)	10.8%	18.7%	19.7%
Parental education (years)	14.5 (1.4)	14.6 (1.7)	14.6 (2.0)
<i>Social smoke exposure</i>			
Adult smoking score (0–10)	.5 (.8)	.3 (.6)	0.3 (.5)
Sibling smokers (number)	.2 (.5)	.2 (.6)	0.2 (.5)
Peer smokers (% none)	79.5%	43.3%	32.6%
Schoolmates seen smoking (% very true)	89.9%	83.6%	82.5%
Teachers seen smoking (% very true)	18.3%	20.4%	18.8%
<i>Psychosocial indicators</i>			
Depression score (0–18)	5.9 (3.3)	5.1 (4.3)	6.2 (4.7)
Stress score (0–45)	4.4 (3.9)	4.0 (4.6)	5.0 (5.1)
Poor academic performance (% very true)	59.9%	63.5%	64.9%
Self-esteem score (0–18)	14.4 (2.5)	14.6 (3.2)	14.9 (3.2)
Novelty-seeking score (0–36)	15.8 (5.2)	15.8 (6.7)	15.5 (6.7)
Impulsivity score (0–28)	7.8 (4.2)	7.7 (5.3)	7.7 (5.7)
<i>Substance use</i>			
Cigar or cigarillo use (% never)	99.4%	99.2%	96.9%
Alcohol use (% never)	67.1%	56.3%	42.8%

Note. *M* = mean. SD = standard deviation.

Table 2

GEE models predicting ND symptoms in adolescent never-smokers.

Predictor	Univariate			Multivariable			Covariates
	b	SE	Wald χ^2	b	SE	Wald χ^2	
<i>Socio-demographics</i>							
Age	−.02	.01	12.31***	−.04	.01	40.84***	Peer smoking, alcohol
Sex							Depression, stress
Female	REF			REF			
Male	.08	.03	8.35**	.01	.02	.11	
Language at home			1.47			1.80	Country of birth, parental education
English	REF			REF			
French	−.02	.03	.49	−.01	.03	.05	
English and French	−.03	.03	1.04	−.02	.03	.39	
Other	.02	.04	.12	.07	.07	1.11	
Country of birth							Language at home
Canada	REF			REF			
Other	−.08	.03	7.71**	−.11	.04	6.04*	
Family income	.04	.04	.91	−.03	.04	.48	Stress, self-esteem
Parental education	.01	.01	.41	.01	.01	.57	Language at home, adult smoking
<i>Social smoke exposure</i>							
Adult smoking	.02	.02	.88	.02	.02	1.25	Parental education
Sibling smoking	.01	.02	.13	.01	.02	.09	
Peer smoking	.09	.02	24.55***	.09	.02	31.10***	Alcohol
Schoolmate smoking	.00	.04	.00	−.02	.04	.43	Teacher smoking
Teacher smoking	.03	.02	2.12	.03	.02	3.73*	Schoolmate smoking
<i>Psychosocial indicators</i>							
Depression	.02	.00	36.77***	.01	.00	5.15*	Stress, self-esteem
Stress	.03	.00	29.41***	.02	.01	13.19***	Depression, self-esteem, impulsivity, family income
Perceived academic performance	−.05	.02	6.41*	−.01	.02	.27	Self-esteem
Self-esteem	−.02	.01	16.71***	−.02	.01	6.22*	Academic performance, family income, stress, depression

Predictor	Univariate			Multivariable			Covariates
	<i>b</i>	SE	Wald χ^2	<i>b</i>	SE	Wald χ^2	
Novelty-seeking	.01	.00	16.06 ***	.00	.00	.03	Impulsivity
Impulsivity	.01	.00	19.59 ***	.01	.00	5.28 *	Novelty-seeking, stress
<i>Substance use</i>							
Cigar or cigarillo	.11	.08	1.82	.10	.09	1.30	Alcohol
Alcohol	.05	.01	12.77 ***	.04	.01	11.29 ***	Peer smoking

Note. All multivariable models also included age and sex as covariates. *b*, unstandardized beta coefficient; SE, standard error; REF, reference category.

* *p* .05.

** *p* .01.

*** *p* .001.