# Measures of nicotine dependence enhance interpretation of number of cigarettes smoked in youth smoking surveillance

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## ABSTRACT

*Background:* Nicotine dependence (ND) symptoms can occur soon after first puff, so that stopping smoking becomes difficult well before 100 cigarettes lifetime is attained. Yet some surveillance systems do not monitor ND symptoms and 100-cigarettes lifetime is used in at least one surveillance system to define current smokers. To assess whether these features limit interpretation of grade-specific data in surveillance, we described smoking and ND symptoms across grade in incident vs. prevalent smokers, and in smokers according to 100-cigarettes lifetime.

*Methods:* Data were available in an investigation of 1294 grade 7 students from 10 Montreal-area high schools followed every 3 months from grade 7 to 11. Analyses described cigarette consumption, 100-cigarette lifetime consumption, cravings, withdrawal symptoms, mFTQ nicotine dependence and ICD-10 tobacco dependence by grade among past 3-month smokers.

*Results:* Despite low cigarette consumption, 21–30% of grade 7 smokers reported ND symptoms. This increased to 27–44% in grade 8 and remained stable thereafter despite increased cigarette consumption. In grade 7, 10% of all smokers had not attained the 100-cigarette milestone but were already dependent. In grade 8, 9, 10 and 11, these proportions were 12%, 8%, 6% and 6%, respectively.

*Conclusions:* ND symptoms should be monitored in youth surveillance systems since they tell a different "story" than cigarettes and their appearance may represent a critical "point-of-no-return." Interventions for incident smokers are needed across grades to stop smoking before ND manifests. Without a shift in focus toward incident rather than established smokers, many children who try cigarettes will become addicted.

## 1. Introduction

Cigarette smoking in youth has declined in the last three decades, but the declines have now slowed (Reid et al., 2017). Worldwide, 11% of youth age 13–15 years smoke (Arrazola et al., 2017). In Canada in 2016–17, 18% of students in grades 7–12 tried cigarette smoking, with prevalence ranging from 9% of grade 7–9 students to 28% of grade 10–12 students (CSTADS, 2016). Mean age at onset is 13.6 years, when students are typically in grade 7 or 8 (CSTADS, 2016). That youth

continue to initiate and sustain smoking necessitates ongoing surveillance to assure that current practices and policies remain optimally designed and targeted to those who will benefit most.

School-based tobacco prevention programs are an important component of tobacco control. Since age/grade in which these programs are delivered is key to effectiveness (Gamache and Stich, 2014), grade-specific surveillance can help pinpoint windows of opportunity for implementing intervention. In Canada, our long-standing youth smoking surveillance system began in 1994. Today the Canadian

Student Tobacco, Alcohol and Drugs Survey (CSTADS) (formerly known as the Youth Smoking Survey (YSS) (CSTADS, 2017) involves biennial cross-Canada surveys of students in grades 7–12 (previous waves also included grades 5 and 6).

A challenge of long-term surveillance systems is whether to incorporate changes reflecting emerging evidence, and which evidence warrants consideration. Despite compelling new findings, decisions may be made to maintain the status quo in terms of content and wording of specific questions in the interests of maintaining comparability across years. This is particularly salient today as youth now commonly use multiple tobacco products as well as non-combustible nicotine delivery systems. Space is limited in surveillance questionnaires, but decisions about content can have major implications in how data are interpreted and used to inform intervention.

In this article, we use grade-specific data from an 18-year study of the natural course of cigarette smoking to reflect on two aspects of youth surveillance which may prevent optimal interpretation of the data and optimal recommendations on the content and timing of intervention. First, should tobacco surveillance measure nicotine dependence (ND) symptoms in addition to cigarette use? Despite evidence that ND symptoms can manifest soon after first puff, that they are associated with sustained smoking (DiFranza et al., 2000, 2007; Gervais et al., 2006; O'Loughlin et al., 2003, 2009; Zhan et al., 2012), that youth experience ND at lower cigarette consumption levels than adults (Kandel and Chen, 2000; Prokhorov et al., 2006; U.S. Department of Health and Human Services, 2010), as well as the fact that most adult surveillance systems monitor ND symptoms (e.g., Global Adult Tobacco Survey 2019; Canadian Community Health Survey 2016; Canadian Tobacco, Alcohol and Drugs Survey 2019, National Adult Tobacco Survey (2014)), ND symptoms are rarely included in youth surveillance systems. For example, the World Health Organization Health Behaviour in School-aged Children Survey (2010) and the European School Survey Project (2015) do not collect data on ND. In Canada, ND symptoms were measured only once in the 2004 YSS. In contrast, the American National Youth Tobacco Survey (NYTS) has collected data on ND symptoms annually since 2012 (2017). Using NYTS data, Caraballo et al. (2009) reported that the relationship between smoking exposure and ND symptoms conforms to the pattern of smoking implied by the sensitization-homeostasis model (DiFranza and Wellman, 2005) in that ND symptoms manifest at low levels of cigarette consumption, even before consumption escalates. We posit that national data on youth ND symptoms can increase understanding of cigarette smoking patterns to better target resources and identify windows for intervention.

Second, we ask whether the 100-cigarette lifetime criterion should be used to characterize adolescent smokers even though numerous reports (DiFranza et al., 2007; Gervais et al., 2006) suggest that ND symptoms can be experienced before this milestone is attained. Although the 100-cigarette indicator is not recommended by the Global Youth Tobacco Survey initiative and is not widely used outside North America (Bondy et al., 2009), it is included in some youth surveillance systems (e.g., the Australian Secondary Students' Alcohol and Drug Survey, the U.S. National Youth Tobacco Survey, CSTADS). In fact, CSTADS uses this criterion to define current daily, non-daily and former smokers. We posit that using 100-cigarettes lifetime to define (current) smokers bypasses an important subgroup of novice smokers who are already dependent, but have not yet attained 100-cigarettes lifetime.

To better understand the utility of data on ND symptoms and 100-cigarettes lifetime in youth surveillance, we studied the links between these variables and number of cigarettes smoked in repeat cross-sectional analyses (by grade) using data collected in an ongoing longitudinal study, thus emulating surveillance. Our specific objectives were to describe cigarette consumption, 100-cigarettes lifetime and ND symptoms in each grade during high school; in incident vs prevalent smokers; and among smokers who did and did not attain 100-cigarettes lifetime.

## 2. Methods

Data were drawn from the Nicotine Dependence in Teens (NDIT) Study, a longitudinal investigation of 1294 grade 7 students recruited in ten high schools in Montreal, Canada in 1999–2000 (O'Loughlin et al., 2015). Self-report questionnaires were completed at school four times in each grade from grade 7 to 11, for a total of 20 cycles in the five years of high school. Two post-high school cycles have been conducted to date, when participants were age 20 and 24 years on average, and a third post-high school cycle is currently ongoing (participants are now age 30 years on average). Baseline characteristics of NDIT participants resembled those of a provincially representative sample of youth age 13 years (O'Loughlin et al., 2015). All students provided assent and parents or guardians provided written informed consent. The study was approved by the Direction de santé publique de Montreal-Centre, the McGill University and the Centre de Recherche du Centre Hospitalier de l'Université de Montréal Ethics Review Boards.

NDIT participants with data on lifetime and past-year smoking and who completed a 3-month recall of cigarette consumption in at least one of the four cycles per grade were retained for analysis. Those who completed the 3-month recall had smoked in one or more of the 3 months preceding the current cycle. To emulate surveillance data to the extent possible, we report data on smokers in each grade so that a single participant can appear in up to five grade-specific analyses (i.e., grade 7–11). Then, to better understand the patterns observed in the data, we studied subgroups of incident and prevalent smokers separately, and subgroups of smokers according to whether the 100-cigarette lifetime milestone was attained.

### 2.1. Study variables

Lifetime smoking history was assessed by: Have you ever in your life smoked a cigarette, even just a puff (drag, hit, haul)? (no; yes, 1 or 2 times; yes 3 or 4 times; yes, 5–10 times; yes, more than 10 times).

Past-year smoking was assessed by: Check the box that describes you best: I have smoked cigarettes, but not at all in the past 12 months; I smoked cigarettes once or a couple of times in the past 12 months; I smoke cigarettes once or a couple of times each month; I smoke cigarettes once or a couple of times each week; I smoke cigarettes every day.

For each of the three months preceding each cycle, participants reported number of days on which they had smoked and average number of cigarettes smoked per day (Centers for Disease Control and Prevention, 1998). These were multiplied and averaged to produce an average number of cigarettes smoked per month in the past three months in each cycle. Test-retest reliability of this measure was adequate (intraclass correlation coefficient = 0.64) (Eppel et al., 2006). We retained, for each participant for each grade, the highest level of cigarette consumption reported in the index grade.

Data on lifetime smoking history and past-year smoking as well as data from the 3-month cigarette smoking recall were also used to categorize participants as incident or prevalent smokers in each grade. Prevalent smokers included participants who indicated having ever smoked prior to the first data collection in each grade. Incident smokers included those who had never smoked prior to the index grade, but who indicated that they had smoked, even just a puff, in one of the four cycles per grade.

Lifetime consumption of 100-cigarettes was measured by: Have you smoked 100 or more whole cigarettes in your life? (100-cigarettes = 4 packs of 25). If the participant reported no in all cycles completed in a single grade, then a "no" was recorded for that grade. A "yes" was recorded if the participant reported "yes" in any cycle.

Four ND indicators were investigated including cravings and withdrawal symptoms, and two multi-item indicators (i.e., the modified Fagerström Tolerance Questionnaire, (mFTQ) (Heatherton et al., 1991), and an indicator based on the six criteria for tobacco dependence (TD)

in the International Classification of Diseases (ICD-10) (World Health Organization, 1992). For cravings and withdrawal, a "yes" was recorded if participants reported strong cravings or frequent withdrawal symptoms in any cycle in a specific grade. Participants who met the criteria in any cycle in a grade were classified as ND (mFTQ) or TD (ICD-10) for that grade.

Supplementary File 1 details the items that comprise each indicator including questionnaire items, response options and if applicable, the psychometric properties and evidence of validity and reliability. In previous work for example (O'Loughlin et al., 2002a, b; Wellman et al., 2006; Contreras et al., 2010), we examined these features of the mFTQ and ICD-10 in a population-based sample of adolescents.

### 2.2. Data analysis

We cross-tabulated cigarette consumption and ND symptoms by grade among all past 3-months smokers, in incident vs. prevalent smokers and among smokers who had or had not attained 100-cigarettes lifetime. Analyses were conducted using SPSS, Version 21.0 (IBM Corp, Armonk, NY. Released 2012).

### 3. Results

Of 1294 participants, 839 (65%) had ever smoked, even just a puff by the end of high school; 424 began before baseline (i.e., prevalent smokers at inception) and 415 began smoking cigarettes during the study (i.e., incident smokers). Of the 839 ever smokers, 687 (82%) had complete data on lifetime and past-year smoking and had completed the 3-month cigarette recall in at least one cycle and were therefore included in the analysis in one or more grades (Supplementary File 2). Table 1 compares baseline characteristics of the 687 smokers retained with those of the 152 not retained (i.e., primarily participants missing data on the 3-month cigarette smoking recall). Higher proportions of participants retained were female, Canada-born, had friends who smoked, were ever smokers in grade 7, smoked more frequently at baseline, and had used other tobacco products. There were no differences between groups in age, language, mother university-educated, lives with one parent only, or parent(s) or sibling(s) smoke.

Mean age in grades 7–11 was 13, 14, 15, 16 and 17, respectively. The analyses for grade 7, 8, 9, 10, and 11 included 362, 393, 351, 302 and 301 participants who reported smoking in the past 3-months in at least one of the four data collections per grade (Table 2). Of these, 84, 84, 51, 30, and 33 participants initiated smoking in grade 7, 8, 9, 10, and 11, respectively. The decline in the total number of smokers with grade likely reflects that some novice smokers discontinued smoking and therefore dropped out of the pool of smokers. Loss-to-follow-up of smokers could also account for the decline, although 79–86% of smokers from the previous grade were retained for analysis in the next grade.

The median number of cigarettes smoked per month among all smokers increased from 3.8 in grade 7 to 28.1 in grade 11 (Table 2). One-third of grade 7 smokers had smoked 100-cigarettes lifetime and this proportion increased to approximately half in grades 9, 10 and 11. Despite low cigarette consumption among grade 7 smokers, 25% reported strong cravings and 30% reported frequent withdrawal symptoms. According to well-established measures, 29% were mFTQ nicotine-dependent and 21% were ICD-10 tobacco-dependent. In grades 8 to 11, the proportion of smokers who reported strong craving remained stable at one-third; withdrawal increased slightly from 36% to 41% across grade; the prevalence of mFTQ nicotine dependence-remained stable at approximately 44%; and ICD-10 tobacco dependence increased somewhat from 27% to 32%. Among ICD-10 tobacco-dependent smokers, 16%, 11%, 3%, 4%, and 1% in grade 7 to 11, respectively had not smoked 100-cigarettes.

**Table 1**

Baseline characteristics of participants retained and not retained for analysis, NDIT Study, 1999–2005 (n = 839).

| | Retained for analysis | | |
| --- | --- | --- | --- |
| | No n = 152 | Yes n = 687 | p-value |
| Age, mean (SD) | 12.8 (0.6) | 12.8 (0.6) | 0.34 |
| Male, % | 63.8 | 39.4 | **≤0.001** |
| French-speaking, % | 70.4 | 63.3 | 0.10 |
| Mother university-educated, % | 31.6 | 31.9 | 0.70 |
| Canada-born, % | 90.8 | 95.2 | **0.03** |
| Lives with one parent only[a], % | 18.8 | 16.6 | 0.52 |
| Parent(s) smoke[a], % | 50.3 | 49.6 | 0.88 |
| Sibling(s) smoke[a], % | 22.8 | 29.6 | 0.10 |
| Friend(s) smoke[a], % | 59.7 | 78.6 | **≤0.001** |
| Ever smoked[a,b], % | 57.3 | 67.1 | **0.02** |
| Past-year smoking[c], % | | | **≤0.001** |
| Never smoked a cigarette, even just a puff | 56.1 | 51.8 | |
| Did not smoke in past year | 38.1 | 14.4 | |
| Smoked once of a couple times in past year | 4.3 | 15.4 | |
| Smoked once or a couple of times each month | 0 | 7.5 | |
| Smoked once or a couple of times each week | 1.4 | 4.2 | |
| Smoked every day | 0 | 6.7 | |
| Lifetime smoking[c], % | | | **≤0.001** |
| Never smoker | 54.3 | 49.5 | |
| Yes, 1 or 2 times | 38.6 | 20.5 | |
| Yes, 3 or 4 times | 2.9 | 8.1 | |
| Yes, 5 or 10 times | 0.7 | 4.5 | |
| Yes, more than 10 times | 3.6 | 17.5 | |
| Used other tobacco products[a], % | 10.7 | 37.9 | **≤0.001** |

[a] Measured in grade 7 (highest level reported amongst the 4 data collection cycles available).

[b] 15 participants were excluded because they did not have smoking data in grade 7.

[c] Measured in survey cycle 1; 54 and 59 participants were missing data at baseline on past-year and lifetime smoking respectively.

### 3.1. Incident smokers

The proportion of incident smokers among all smokers declined from 23% in grade 7 to 11% in grade 11 (Table 2), likely reflecting depletion of the pool of never-smokers susceptible to smoking over time. Cigarette consumption per month among incident smokers was low (i.e., less than one cigarette per month) and did not vary substantially across grade (median 0.3–0.8 cig/month). Similarly, the proportion of incident smokers who reported 100-cigarettes lifetime was stable (11–16%) across grades, with the exception that only 3% reported 100-cigarettes lifetime in grade 10. The proportion of incident smokers who reported strong cravings (9–14%) and frequent withdrawal (10–14%) was relatively stable across grades (although no incident grade 11 smokers reported strong cravings). Similar to results for prevalent smokers, the mFTQ consistently overestimated ND relative to the ICD-10 in incident smokers, possibly because the mFTQ is a less conservative measure of ND and it includes cigarette consumption. The prevalence of mFTQ ND ranged between 6% and 16% among incident smokers across grade, and the prevalence of ICD-10 tobacco dependence ranged between 3% and 11%.

Among ICD10 tobacco-dependent smokers, the median number of cigarettes smoked per month increased from 50 in grade 7 to 240 in grade 8. Fewer incident smokers in grades 10 and 11 (3–10%) were mFTQ or ICD-10 dependent than in grades 8 and 9 (6–16%).

### 3.2. Prevalent smokers

Among prevalent smokers, the median number of cigarettes smoked per month increased over time from 6.8 in grade 7 to 49.8 (1.7 cigarettes per day) in grade 11, and 100-cigarettes lifetime increased steadily

**Table 2**
Cigarette consumption and nicotine dependence symptoms among incident and prevalent smokers by grade, NDIT Study, 1999–2005.

| Grade | Smoked in the past 3 months n Total n | % all smokers in grade | No. cig/ month Median (IQR) | 100-cigarettes lifetime % | Strong craving % | Frequent withdrawal symptoms % | mFTQ nicotine dependent % | ICD-10 tobacco dependent % | No. cig/month Median (IQR) |
|---|---|---|---|---|---|---|---|---|---|
| Total | | | | | | | | | |
| 7 | 362 | 100 | 3.8 (44.7) | 31.3 | 25.1 | 29.9 | 29.1 | 20.7 | 135.0 (436.3) |
| 8 | 393 | 100 | 13.7 (148.0) | 46.8 | 31.3 | 35.7 | 43.5 | 26.5 | 240.0 (349.7) |
| 9 | 351 | 100 | 13.0 (239.3) | 53.6 | 33.7 | 38.3 | 43.9 | 27.1 | 340.0 (383.3) |
| 10 | 302 | 100 | 15.3 (239.2) | 57.0 | 32.5 | 39.9 | 46.7 | 29.5 | 340.0 (451.9) |
| 11 | 301 | 100 | 28.1 (242.1) | 58.1 | 35.1 | 40.7 | 45.9 | 31.6 | 390.0 (480.3) |
| Incident smokers | | | | | | | | | |
| 7 | 84 | 23.2 | 0.6 (4.3) | 10.7 | 12.5 | 11.3 | 5.6 | 6.0 | 50.0 (93.8) |
| 8 | 84 | 21.4 | 0.6 (5.1) | 15.5 | 13.9 | 14.1 | 15.3 | 10.7 | 240.0 (353.3) |
| 9 | 51 | 14.5 | 0.6 (4.2) | 16.0 | 9.3 | 14.0 | 16.3 | 9.8 | 226.7 (484.2) |
| 10 | 30 | 9.9 | 0.3 (0.8) | 3.3 | 12.0 | 12.0 | 8.0 | 3.3 | * |
| 11 | 33 | 11.0 | 0.8 (2.4) | 12.1 | 0.0 | 9.7 | 9.7 | 3.0 | ** |
| Prevalent smokers | | | | | | | | | |
| 7 | 278 | 76.8 | 6.8 (82.7) | 37.5 | 28.5 | 34.8 | 35.5 | 25.2 | 186.2 (432.0) |
| 8 | 309 | 78.6 | 32.1 (207.9) | 55.3 | 35.7 | 41.0 | 50.5 | 30.7 | 240.0 (385.0) |
| 9 | 300 | 85.5 | 35.3 (278.1) | 59.9 | 37.4 | 42.0 | 48.1 | 30.0 | 340.0 (391.5) |
| 10 | 272 | 90.1 | 63.9 (238.8) | 62.9 | 34.5 | 42.6 | 50.4 | 32.4 | 340.0 (483.3) |
| 11 | 268 | 89.0 | 49.8 (311.8) | 63.8 | 39.1 | 44.4 | 50.2 | 35.1 | 390.0 (463.8) |

* Includes only one participant (smoked 208.0 cig/month).
** Includes only one participant (smoked 62.5 cig/month).

from 38% in grade 7 to 64% in grade 11 (Table 2). Despite increases in cigarette consumption after grade 7, the proportion of prevalent smokers reporting strong cravings or frequent withdrawal did not increase markedly. Dependence did not exceed 50% (mFTQ) or 35% (ICD-10) in any grade. Half of prevalent smokers were mFTQ-dependent by grade 8. ICD-10 dependence also appeared to stabilize at approximately 30% by grade 8.

*3.3. 100 cigarettes lifetime*

The proportion of smokers who had not attained 100-cigarettes lifetime was 69%, 53%, 46%, 43% and 42% in grade 7–11, respectively (Table 3). Despite low cigarette consumption (i.e., median 0.8–1.2 cig/month), 3–13% of smokers who had not attained 100-cigarettes lifetime reported strong craving or frequent withdrawal symptoms, 5–11% were mFTQ nicotine-dependent and 1–5% were ICD-10 tobacco-dependent.

Among those who had attained 100-cigarettes lifetime, 53–64% reported strong craving or frequent withdrawal symptoms, 71–75% were mFTQ nicotine-dependent and 50–56% were ICD-10 tobacco-dependent.

Among all smokers in grade 7–11, 10%, 12%, 8%, 6% and 6%, respectively had not attained the 100-cigarette milestone, but were mFTQ nicotine- or ICD-10 tobacco-dependent. These novice smokers would not have been defined as current smokers in some surveillance systems, despite their high risk of sustained smoking.

**4. Discussion**

In this study, we examined grade-specific prevalence of ND including two specific symptoms (i.e., craving, withdrawal) and two multidimensional ND indicators (i.e., mFTQ, ICD-10 tobacco dependence) as well as 100-cigarettes lifetime to speculate how these data

**Table 3**
Cigarette consumption and nicotine dependence symptoms among smokers who did and did not attain 100-cigarettes lifetime by grade, NDIT Study, 1999–2005.

| | Past 3-month smokers Total n* | % all smokers in grade | No. cig/month Median (IQR) | Strong craving % | Frequent withdrawal symptoms % | mFTQ nicotine dependent % | ICD10 tobacco dependent % |
|---|---|---|---|---|---|---|---|
| Attained 100 cigarettes Grade | | | | | | | |
| 7 | 113 | 31.3 | 127.5 (346.4) | 56.6 | 63.7 | 70.8 | 55.8 |
| 8 | 184 | 46.8 | 157.8 (338.7) | 54.3 | 57.9 | 75.0 | 51.1 |
| 9 | 186 | 53.6 | 240.0 (399.1) | 55.7 | 62.3 | 71.9 | 49.5 |
| 10 | 172 | 57.0 | 205.0 (315.0) | 52.6 | 60.6 | 75.4 | 50.6 |
| 11 | 175 | 58.1 | 240.0 (333.0) | 54.3 | 61.7 | 73.1 | 53.7 |
| Did not attain 100 cigarettes Grade | | | | | | | |
| 7 | 248 | 68.7 | 1.2 (5.1) | 9.3 | 12.6 | 8.0 | 4.8 |
| 8 | 209 | 53.2 | 0.8 (4.0) | 6.9 | 12.5 | 10.7 | 4.8 |
| 9 | 161 | 46.4 | 0.8 (2.5) | 5.7 | 8.4 | 8.5 | 1.9 |
| 10 | 130 | 43.0 | 0.8 (2.3) | 3.4 | 10.2 | 5.1 | 1.5 |
| 11 | 126 | 41.9 | 0.8 (3.7) | 6.0 | 8.7 | 5.1 | 0.8 |

* Totals differ because of missing data.

might affect interpretation of surveillance data. A finding of considerable interest is that, while number of cigarettes smoked per month increased steadily with grade, the prevalence of the ND indicators plateaued after grade 7. This pattern suggests that not all novice smokers will experience ND symptoms or become dependent, that there may be an upper limit in the proportion of novice smokers that experience ND symptoms, and that the limit is attained relatively early in high school. Alternatively, increasing frequency of smoking in later grades may mask ND symptoms due to short-interval smoking, pre-empting the latency period for ND symptoms.

The data suggest that an increase from 4 to 14 cigarettes per month from grade 7 to 8 may influence ND symptoms more than an increase from 13 to 28 cigarettes per month from grade 9 to 11. There are at least two possible explanations. First there may be a threshold in the number of cigarettes smoked after which ND symptoms begin to manifest. Our data suggest that this threshold may be attained between grade 7 and 8, and thereafter, adolescents can smoke similar amounts or more without increasing dependence. Second, these observations are consistent with brain sensitivity in early adolescence (DiFranza, 2015; Kandel and Chen, 2000; U.S. Department of Health and Human Services, 2014). Animal studies provide evidence of increased sensitivity to nicotine in early adolescence compared to middle or late adolescence (Adriani et al., 2002) suggestive that nicotine alters activity in two areas of the adolescent brain important to addiction: the hippocampus which is important in learning and memory, and the midbrain, a center for the reward and addiction pathways (Slotkin, 2002). Earlier exposure to nicotine may derange the normal course of brain maturation and have lasting consequences on cognitive ability, mental health, and personality (Brook et al., 2004; Brown et al., 1996; Choi et al., 1997; Deas and Brown, 2006; Richards et al., 2003). A recent longitudinal study in adolescents reported that a one-year increase in age at initiation was associated with smoking fewer cigarettes per month and a lower Fagerström Test for Nicotine Dependence score (Buchmann et al., 2013). Novice smokers with similar cigarette consumption, for example, could have different risks of sustained smoking depending on the extent to which ND symptoms manifest (Selya et al., 2016).

Whatever the mechanistic underpinning, that cigarette consumption increases while the prevalence of ND symptoms remains stable after grade 7 signals a dissonance that could lead to faulty recommendations in terms of tobacco control intervention. Specifically, if number of cigarettes consumed is the primary indicator of the risk of sustained smoking, then the recommendation in terms of timing for prevention would be when or shortly before some critical number of cigarettes (e.g., 100 cigarettes lifetime) is consumed. However, if ND symptoms are better indicators of risk than quantity smoked, then risk is established very early (in grade 7 or before) in many novice smokers, regardless of increasing cigarette consumption. If this is the case, then in addition to prevention, cessation programs are needed early in high school to help adolescents recognize their ND symptoms as a critically urgent indicator to stop smoking before they become long-term smokers. In addition, if number of cigarettes smoked and ND symptoms "decouple" over time, urgent measures should be taken when any incident smoking occurs. Without a shift in clinical and public health messaging toward incident rather than prevalent smoking, many more children will become addicted to tobacco products than need be.

### 4.1. Incident vs prevalent smokers

An important distinction sometimes overlooked in surveillance is whether young smokers are prevalent or incident smokers. While the biological effects of nicotine may vary by sex or genetic predisposition, prevalent smokers have had more time than incident smokers to establish smoking patterns and for the impact of exposure to nicotine to manifest. In this analysis, incident smokers had not smoked in the previous grade, but became smokers in the index grade. In these

smokers, cigarette consumption was very low and similar across grade.

Notably, regardless of low cigarette consumption, approximately 12% of incident smokers reported cravings and/or withdrawal symptoms, and up to 16% were already mFTQ dependent. This subgroup of incident smokers could represent individuals with high affinity for nicotine (or some other smoking-related feature) who escalate consumption rapidly and become addicted within days, weeks or months of first puff. The proportion of dependent incident smokers declined in later grades, which could reflect brain sensitivity in early vs. later adolescence or could be explained by the fact that those with high affinity initiated earlier.

Since prevalent smokers comprise 77–90% of the grade-specific samples, the findings in the overall sample mirror the findings among prevalent smokers primarily (i.e., that cigarette consumption generally increases with grade, but the percent with ND symptoms, mFTQ and ICD-10 dependence is established in grade 8 and remains steady thereafter). The discordance between quantity smoked and ND is even more apparent when the sample is restricted to prevalent smokers.

### 4.2. 100-cigarettes lifetime

Validation of the 100-cigarette lifetime criterion suggests a 1–3% decrease in the prevalence of current smoking among adults when the 100-cigarette criterion is used in conjunction with past 30-day prevalence or current smoking (Bondy et al., 2009). In our data, the sensitivity of this criterion in identifying novice smokers with ND symptoms (i.e., a subgroup that likely needs cessation rather than prevention intervention) was 65% in grade 7, increasing to 89% in grade 11. Specificity ranged from 92% in grade 7 to 77% in grade 11. The 100-cigarette criterion is therefore not optimal in earlier grades because it bypasses novice smokers with ND symptoms who have not attained 100 cigarettes lifetime. Reliance on the 100-cigarette criterion can therefore mislead identification of optimal timing for intervention as well as target groups needing intervention.

### 4.3. Prevention or cessation

Surveillance is a critical component of comprehensive tobacco control systems because it provides evidence to ensure that practices and policies remain optimally designed and delivered to those who will benefit most (World Health Organization, 2019). Existing youth prevention programs usually incorporate didactic material and/or counseling approaches that aim to prevent first puff and may not address ND symptoms (Thomas et al., 2013; Carson-Chahhoud et al., 2017). We would argue that the time window for prevention has been bypassed the moment ND symptoms manifest. Rather cessation interventions are needed to decrease cigarette consumption, prevent the progression of ND symptoms, and help novice smokers learn about alternate strategies to cope with ND symptoms. Inclusion of ND symptoms in surveillance will help differentiate when smokers manifest ND symptoms and identify the time window for cessation intervention.

### 4.4. Limitations

Self-report data on smoking were not validated biochemically but are typically reliable and valid (Wong et al., 2012). While smoking has declined considerably since 1999–2005 when these data were collected, the findings are important for two reasons: (i) many adolescents continue to initiate smoking; and (ii) the patterns of escalation leading to ND observed in this database likely remain relevant because the effect of nicotine on the developing brain has likely remained unchanged. Although the data presented predates widespread availability of electronic cigarettes, this type of formative ND research remains highly relevant in the current landscape of expanding tobacco product choices and easy access to high potency nicotine products in early adolescence. Finally, selection bias due to loss-to-follow-up is possible and use of a

purposive sample may limit generalizability of the findings.

## 5. Conclusions

These data show that despite low cigarette consumption, novice smokers in high school experience ND symptoms; the 100-cigarette lifetime criterion fails to identify a subgroups of novice smokers who are already dependent; incident smokers manifest ND symptoms across all grade levels studied; and cigarette consumption increases over time while ND symptoms and both ICD-10 and mFTQ dependence appear to stabilize.

We suggest that, if a central objective of surveillance is to guide intervention, then we are not asking all the right questions. We propose that ND symptoms be monitored by age/grade in surveillance systems, since their appearance red flags a critical milestone in the pathway to sustained smoking. Further, in early grades, the sensitivity of the 100-cigarette criterion in identifying novice smokers at risk of sustained smoking is poor. Early adolescent smokers are at high risk of ND not necessarily because they have smoked a certain number of cigarettes, but because they are exposing their developing brains to nicotine. Therefore, any adolescent using tobacco products that contain nicotine should be a high priority target for urgent intervention, no matter how many times they have smoked cigarettes. Without this shift in clinical and public health approaches toward incident rather than established smoking, children will continue to become addicted to nicotine.

### Role of funding source

### Contributors

ED reviewed the literature, conducted the data analysis, contributed to the design of the analysis and interpretation of data, and wrote the article. RJW and MPS reviewed the literature, contributed to the design of the analysis and interpretation of data, and drafted sections of the article. JW and AM contributed to the interpretation of data, and drafted sections of the article. JOL designed the study, obtained the funding, developed the survey instruments, supervised data collection, contributed to the design of the analysis and interpretation of data, coordinated drafting the article, and wrote sections of the article. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

### Declarations of Competing Interest

None.

### Availability of data and material

Data are available upon request. To gain access, applicants must complete a data access form available on our NDIT website (www.nditstudy.ca) and return it to the principal investigator (jennifer.oloughlin@umontreal.ca).

The procedure to obtain access to NDIT data is described in O'Loughlin, J., Dugas, E. N., Brunet, J., DiFranza, J., Engert, J. C., Gervais, A., Gray-Donald, K., Karp, I., Low, N. C., Sabiston, C., Sylvestre, M. P., Tyndale, R. F., Auger, N., Belanger, M., Barnett, T., Chaiton, M., Chenoweth, M. J., Constantin, E., Contreras, G., Kakinami, L., Labbe, A., Maximova, K., McMillan, E., O'Loughlin, E. K., Pabayo, R., Roy-Gagnon, M. H., Tremblay, M., Wellman, R. J., Hulst, A., Paradis, G., 2015. Cohort Profile: The Nicotine Dependence in Teens (NDIT) Study. Int J Epidemiol. 44(5), 1537-1546. doi: 10.1093/ije/dyu135. The relevant paragraph is described below. This process has been approved by the ethics committee at the CRCHUM.

Access to NDIT data is open to any university-appointed or affiliated investigator upon successful completion of the application process. Masters, doctoral and postdoctoral students may apply through their primary supervisor. For more information, visit www.nditstudy.ca or contact the Principal Investigator.

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### Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.drugalcdep.2019.06.036.

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