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Measures of nicotine dependence in adolescents: An update of the evidence 2000–2010

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Abstract. Nicotine withdrawal and the compulsion to use tobacco resulting from withdrawal form the core clinical features of nicotine dependence (ND). However, some ND measures show little or no content overlap with these clinical features. Our objective was to review the content and psychometric properties of available measures of ND for youth. A literature search identified 27 English language articles published in 2000–2010 that evaluated ND measures in adolescents or young adults. A consensus process among the authors was used to establish if each item in each measure assessed withdrawal or compulsion, or if the item tapped other aspects of cigarette smoking including tolerance, harm, triggers for smoking, cigarette use patterns, prioritizing smoking, perceived utility, or attitudes about smoking. Out of 14 measures identified, three (Hooked on Nicotine Checklist, Latency to Withdrawal, Withdrawal Symptom Cluster) measured the core clinical features of ND; six (Autonomy Over Smoking Scale, DSM IV, Dimensions of Tobacco Dependence Scale, ICD-10 Tobacco Dependence, ND/Cravings Symptom Cluster, Nicotine Dependence Syndrome Scale) measured withdrawal/compulsion and other aspects of smoking; and five (Fagerström Test for Nicotine Dependence, Modified Fagerström Tolerance Questionnaire, Nicotine Dependence Scale for Adolescents, Self-Medication Symptom Cluster, Stanford Dependence Index) had few or no withdrawal/compulsion indicators. Existing measures vary widely in the degree to which they assess the known clinical features of ND. Attempts to assess ND indirectly in youth by measuring other aspects of smoking may result in inaccuracy if items are endorsed for reasons other than ND. No existing measure assesses the full spectrum of clinically recognized features of ND.

Keywords: Nicotine, dependence, adolescents, measurement

1. Introduction

Smoking and nicotine dependence (ND) in adolescents remain critical public health issues, but advances in research that could inform the development of effective tobacco control programs for youth is impeded because there is no standardized, widely accepted measure of ND for youth. This gap contributes to a lack of consistency across studies in findings related to the prevalence, natural course, determinants, and outcomes of ND.

Ten years ago, Colby et al. [1] reviewed existing measures of ND for youth and concluded that more research is needed to develop theoretically coherent, clinically

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relevant, and psychometrically sound measures. In the ensuing ten years, knowledge about the clinical presentation and natural course of ND in youth has consolidated, and it is important that any measure of ND for youth incorporate this new knowledge. More specifically, there is growing understanding that the physiologic abnormality that characterizes ND and allows for its diagnosis is a withdrawal state that emerges whenever an addicted user attempts to forgo use [2]. Nicotine withdrawal creates a compulsion to use tobacco that forms the core clinical feature of the disorder. Clinically relevant symptoms of withdrawal include wanting to use tobacco, craving tobacco, needing tobacco, irritability, anxiety, anger, restlessness, moodiness, impatience, and difficulty concentrating [2,3]. Withdrawal symptoms appear after a delay, or latency, after the last use of tobacco which may be as short as a few minutes or as long as several weeks [4].

DiFranza et al. [2] characterized the natural course of ND based on this understanding of ND. The earliest recognized symptom of nicotine withdrawal is wanting to use tobacco, which is typically mild, short-lived, and fairly easy to ignore [2]. Recurrent periodic wanting, a prodromal symptom that heralds the onset of physiologic dependence, is often the first ND symptom to present. At the onset of addiction, a single use of tobacco provides prompt relief from withdrawal symptoms for days or weeks at a time [2]. However, as tolerance develops, withdrawal symptoms appear with a shorter latency after the last use and the individual is compelled to use tobacco at more frequent intervals to maintain comfort. The shortening of the latency is the only form of nicotine tolerance that is a manifestation of ND [4–6]. With continued abstinence, wanting is replaced by craving, a desire to use tobacco that is more intense, persistent, and intrusive on the user's concentration, and therefore difficult to ignore. As withdrawal progresses, craving transitions to needing, meaning that craving and other withdrawal symptoms are so troublesome that the person feels an urgent need to use tobacco to feel and function normally [2]. Symptoms of intensifying nicotine withdrawal produce a compulsion to use tobacco, which signifies a loss of autonomy for smokers as their efforts to limit or curtail tobacco use fail. Since no other condition causes a compulsion to use tobacco, it is a pathognomonic indicator of ND. In this paradigm, no other symptom is required to make the diagnosis [2,7].

In addition to this characterization of the clinical features of ND, new knowledge has emerged in the past ten years concerning its natural course in youth. It is now well-established that most adolescent smokers have ND symptoms well before they progress to daily smoking [8–12]. ND in youth can occur with any form of tobacco or level of use, with no prerequisites in terms of minimum age, duration of tobacco use, daily use, or amount of daily consumption, and early ND symptoms are highly predictive of subsequent tobacco use [9,13].

The objective of this article is to examine what we have learned about the measurement of ND in adolescents in 10 years since the article published by Colby et al. [1]. More specifically, we summarized recent evidence on the reliability and validity of new and existing ND measures, and we assessed how these measures stack up against what is now known about the defining clinical features of ND including withdrawal and compulsion to smoke.

2. Methods

English language articles on the measurement of ND in adolescents published from 2000 to 2010 were identified through the PubMed search engine with keywords including nicotine, smoking, dependence, adolescents, youth, measurement, validation, and scale. Articles identified were screened for the following inclusion criteria, (i) the study included a population-based sample of adolescents and/or young adults (i.e., articles using clinical populations were excluded); and (ii) the article reported indicators of the validity and/or reliability of the ND scale assessed. Articles published in 2000 but reviewed by Colby et al. [1] were excluded. Additional articles that met the inclusion criteria were identified by scanning references in all publications reviewed, as well as through the authors' knowledge of those literatures.

To assess how the ND measures identified in the search stack up against the paradigm that withdrawal and compulsion to use tobacco are pathognomonic ND indicators, the authors discussed each item in each scale to arrive at a consensus on how to classify the item into one of nine content categories including:

(i) *Withdrawal/compulsion* is the urge to use tobacco as evidenced by wanting, craving, needing, feeling addicted, or an inability to curtail or refrain from use. Based on our current understanding of ND, items that measure these symptoms are valid indicators of ND [2]. Items were placed in this category only if they were not likely to be endorsed by smokers who

are not ND. The item 'Do you smoke?' for example, would be rejected as a valid measure of ND because it would be endorsed by all non-ND smokers.

(ii) *Tolerance* – A single drug can produce many effects and side effects. Tolerance can develop separately to each intended and unintended effect of a drug, and therefore there are many forms of tolerance to nicotine. Tolerance to the nausea, dizziness, cough, 'buzz', skin conductance and cardiovascular effects of nicotine are not indicators of addiction [14]. The only form of nicotine tolerance that is an indicator of addiction is the shortening of the latency that prompts smokers to smoke at more frequent intervals to keep withdrawal at bay [4, 15]. Further, more frequent smoking is an indicator of ND only when it is attributable to a shortening latency. More frequent smoking related to more opportunities to smoke or increased availability of cigarettes is not a clear indication of ND. Since the latency shortening process operates even before smokers are smoking one cigarette per week, there are no cutoff values for smoking frequency that indicate tolerance [4].

(iii) *Harm* – Smoking despite known risks is not an unequivocal indication of addiction because both dependent and non-dependent smokers may continue to smoke in spite of illness or known health risks. Non-dependent smokers for example, may have the attitude that everyone must die from something, so why not enjoy smoking.

(iv) *Triggers* for smoking are situations or emotions that prompt a desire to use tobacco. We are not aware of any evidence establishing that smoking in response to triggers is an unambiguous indication of addiction.

(v) *Cigarette use pattern* – When ND is present, the shortening of the latency to needing a cigarette influences smoking patterns. Smokers with latency to needing a cigarette that is shorter than the amount of time they spend sleeping will experience a need to smoke soon after awakening. However, addicted adolescent smokers may not feel compelled to smoke upon awakening if their latencies are longer than their time sleeping. As ND develops, ND symptoms accumulate quickly while the escalation in smoking frequency may lag, such that adolescent smokers display many more ND symptoms than would be expected at a given frequency of smoking, compared to adults [10, 16]. If smoking frequency is an indicator of ND severity, it would produce differential item functioning across adolescents and adults, also because blacks metabolize nicotine slower than whites [17], across races as well [18–25].

(vi) *Prioritizing smoking* – The urgency of needing to smoke may prompt addicted smokers to make smoking a priority. However, smoking may take precedence for many reasons unrelated to addiction such as personal preferences, attitudes, and values.

(vii) *Perceived utility* – Individuals come to rely on smoking as a mechanism for coping with situations or emotions such as anger, boredom, and stress [26]. Reliance on smoking as a coping mechanism correlates very highly with direct measures of ND such as withdrawal [26]. It is not known whether this reliance derives from physiologic addiction, a process of learning/conditioning, or if the pharmacologic properties of nicotine relate to self-medication.

(viii) *Attitudes* about tobacco use are neither a direct nor indirect indicator of ND.

(ix) *Unclassifiable* – This categorization was used when it was unclear what the item measured.

After categorizing each item in each scale according to its content, we then assigned each scale to one of three categories based on what the items in the scale measured: (i) scale in which all or most items measure withdrawal/compulsion, (ii) mixed scale that measures withdrawal/compulsion and other aspects of smoking, or (iii) scale with few/no items that measure withdrawal/compulsion.

To assess and compare the psychometric properties of the ND measures, the following data were extracted from each article retained into tables for review: study population, sample size, indicators of reliability of the ND scale, indicators of validity of the ND scale, and results of cross-structure analyses of scale comparison [27].

3. Results

Among 38 articles identified in the PubMed search, 27 met the inclusion criteria and were retained for anal-

ysis. Fourteen distinct ND measures used with adolescents were identified in the 27 articles. Table 1 lists the items that comprise each measure and their response options, and indicates how each item was categorized into the nine content categories. Table 2 summarizes 23 articles that reported the psychometric properties of a specific measure, and Table 3 summarizes nine studies that compared measures.

We categorized three measures (Hooked on Nicotine Checklist, Latency to Withdrawal, Withdrawal Symptom Cluster) as measuring ND exclusively or primarily; six measures (Autonomy Over Smoking Scale, DSM-IV, Dimensions of Tobacco Dependence Scale, ICD-10 Tobacco Dependence, ND/Cravings Symptom Cluster, Nicotine Dependence Syndrome Scale) as including a mix of ND and other items; and five measures (Fagerström Test for Nicotine Dependence, Modified Fagerström Tolerance Questionnaire, Nicotine Dependence Scale for Adolescents, Self-Medication Symptom Cluster, Stanford Dependence Index) as having few or no withdrawal/compulsion indicators (Table 1).

3.1. Scales that measure withdrawal/compulsion

Nine of the 10 items in the Hooked on Nicotine Checklist (HONC) [28] measure withdrawal/compulsion, albeit with simple dichotomous response choices (yes or no). Because reasons other than ND such as rebellion could result in adolescents finding it difficult to refrain from smoking when prohibited, the item "Is it hard to keep from smoking in places where you are not supposed to, like school?" and similarly worded items in other measures were categorized as Unclassifiable. Five studies reported the psychometric properties of the HONC in adolescents, and five compared the HONC with other measures. The internal consistency of the HONC was consistently high (α ranged from 0.83 to 0.94). Test-retest reliability was moderate to excellent across HONC items. The HONC was associated with amount and frequency of smoking, duration of tobacco use, age at first use, daily smoking [29], failed quit attempts [29–31], and self-reported smoking behavior [28]. Further it predicted smoking at 6- and 12-months follow-up [32]. The HONC demonstrates convergent construct validity against the Fagerström Test for Nicotine Dependence (FTND), saliva cotinine levels [33] and the Autonomy over Tobacco Scale (AUTOS) [26]. It has generally superior properties than the Modified Fagerström Tolerance Questionnaire (mFTQ) [32]. Two studies reported a single-factor solution for the HONC [29,34], whereas Kleinjan et al. [35] reported a two-factor solution.

Two reports evaluate a single-item measure of time from last cigarette to onset of withdrawal symptoms. In a national survey, Latency to Withdrawal (LTW) correlated negatively ($r = -0.53$) with smoking frequency among 2,350 youth who smoked < 6 cigarettes daily, and among 745 youth who smoked $\geqslant 6$ cigarettes daily ($r = -0.23$) [15]. In a replication study, LTW correlated negatively with smoking frequency (Kendall's tau $b = -0.53$), age at smoking initiation ($b = -0.25$), duration of tobacco use ($b = -0.25$), and a withdrawal symptom score ($b = -0.44$) [4].

The Withdrawal Symptom Cluster scale was developed in the Nicotine Dependence in Teens (NDIT) Study [36]. It comprises six items with 4-point Likert type response choices, all of which measure withdrawal/compulsion. Internal consistency ($\alpha = 0.88$) and test-retest reliability (ICC $= 0.78$) are moderate, and scores on the scale show convergent construct validity against quit attempts and smoking status. To date, no other study has reported the reliability or validity of this scale.

3.2. Mixed scales

The Autonomy over Smoking Scale (AUTOS) was developed to measure change in number and intensity of withdrawal symptoms, cue-induced craving, and psychological dependence [26]. Four of the 12 items measure ND, while eight measure utility and triggers. In a sample of 1055 students, the scale had high internal consistency ($\alpha = 0.96$), and inter-item correlations ranged from 0.51–0.87. The scale correlated with age at smoking initiation and failed quit attempts. It was highly correlated with the HONC and moderately correlated with number of DSM-IV criteria. To date, no other study has tested the reliability or validity of this scale in adolescents.

The DSM-IV measure of ND consists of nine items covering the seven DSM-IV criteria (tolerance, withdrawal, increased substance use over time, unsuccessful attempts to cut back or stop, time spent obtaining the substance, interference with social activities, use despite physical problems). Only two items measure withdrawal/compulsion. Internal consistency ranged from 0.70–0.90 depending on whether the DSM-IV measure was treated as a set of subscales (one for each of the seven criteria) or as a single scale based on a single factor [37,38]. Exploratory factor analysis supports a single factor, and there are no confirmatory factor an-

Table 1
Items included in nicotine dependence measures for adolescents according to item content category

	Item content category
I. SCALES THAT MEASURE WITHDRAWAL/COMPULSION	
Hooked on Nicotine Checklist (HONC) (28)	
Please answer "yes" or "no" to the following questions:	
1. Have you ever tried to quit but couldn't?	Withdrawal/compulsion
2. Do you smoke now because it is really hard to quit?	Withdrawal/compulsion
3. Have you ever felt like you were addicted to tobacco?	Withdrawal/compulsion
4. Do you ever have strong cravings to smoke cigarettes?	Withdrawal/compulsion
5. Have you ever felt like you really needed a cigarette?	Withdrawal/compulsion
6. Is it hard to keep from smoking in places where you are not supposed to, like school?	Unclassifiable
When you tried to stop smoking (or when you haven't used tobacco for a while…)	
7. Did you find it hard to concentrate because you couldn't smoke?	Withdrawal/compulsion
8. Did you feel more irritable because you couldn't smoke?	Withdrawal/compulsion
9. Did you feel a strong urge or need to smoke?	Withdrawal/compulsion
10. Did you feel nervous, restless or anxious because you couldn't smoke?	Withdrawal/compulsion
Latency to Withdrawal (LTW) (4)	
1. After you have smoked a cigarette, how long can you go before you feel you need to smoke again? (weeks, days, hours, minutes)	Withdrawal/compulsion
Withdrawal Symptom Cluster (31)	
Think about the times when you have cut down or stopped using cigarettes or when you haven't been able to smoke for a long period (like most of the day). How often did you experience the following? (never; rarely; sometimes; often)	
1. Feeling irritable	Withdrawal/compulsion
2. Feeling restless	Withdrawal/compulsion
3. Feeling nervous, anxious or tense	Withdrawal/compulsion
4. Trouble concentrating	Withdrawal/compulsion
5. Feeling a strong urge or need to smoke	Withdrawal/compulsion
6. Trouble sleeping	Withdrawal/compulsion
II. MIXED SCALES	
Autonomy Over Smoking Scale (AUTOS) (26)	
Please indicate which response describes you best (not at all; a little; pretty well; very well)	
Withdrawal symptoms	
1. When I go too long without a cigarette, I get impatient.	Withdrawal/compulsion
2. When I go too long without a cigarette, I get strong urges that are hard to get rid of.	Withdrawal/compulsion
3. When I go too long without a cigarette, I lose my temper more easily.	Withdrawal/compulsion
4. When I go too long without a cigarette, I get nervous or anxious.	Withdrawal/compulsion
Psychological dependence	
5. I rely on smoking to focus my attention.	Utility
6. I rely on smoking to take my mind off being bored.	Utility
7. I rely on smoking to deal with stress.	Utility
8. I would go crazy if I couldn't smoke.	Utility
Cue-induced craving	
9. When I feel stressed, I want a cigarette	Trigger
10. When I see other people smoking, I want a cigarette	Trigger
11. When I smell cigarette smoke, I want a cigarette	Trigger
12. After eating, I want a cigarette	Trigger
DSM-IV (38)	
Tolerance as defined by either of the following: (a) need for markedly increased amounts to achievei intoxication or desired effect; (b) markedly diminished effect with continued use of the same amount	
1. Compared to when you first started smoking do you need to smoke more now in order to feel satisfied or get the same effect? (not at all; a little bit; somewhat; quite a bit)	Tolerance
2. Do you find you can smoke more without experiencing effects like nausea, lightheadedness, or dizziness? (not at all; a little bit; somewhat; quite a bit)	Tolerance
Withdrawal, as manifested by either of the following (a) or (b)	
(a) Characteristic withdrawal syndrome (both A and B)	

Table 1, continued

	Item content category
A. Daily use of nicotine for at least several weeks	
B. Abrupt cessation or reduction in the amount of nicotine use, followed within 24 hours 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	
1. When you stop, cut down, or go without smoking now, how much do you experience the following? (not at al; a little bit; somewhat ; quite a bit)	Withdrawal/compulsion
(1) Feeling sad, blue, or depressed	
(2) Difficulty sleeping	
(3) Frustrated or angry (or feeling irritable)	
(4) Feeling tense or anxious	
(5) Difficulty concentrating	
(6) Restlessness or impatience	
(7) Increased appetite or weight gain	
2. How often do you smoke now to keep from feeling this way or to stop feeling this way? (not at all; a little bit; somewhat; quite a bit)	Pattern
The substance is often taken in larger amounts or over a longer period than was intended	
1. How often do you smoke even though you promise yourself you won't? (not at all; a little bit; somewhat; quite a bit)	Pattern
2. How often do you smoke more frequently or for more days in a row than you intend? (not at all; a little bit; somewhat; quite a bit)	Pattern
There is a persistent desire or unsuccessful attempts to cut down or control substance use	
1. How often do you try to stop or cut down on your smoking but are unable to do so? (not at all; a little bit; somewhat; quite a bit)	Withdrawal/compulsion
A great deal of time is spent in activities necessary to obtain the substance or recover from its effects	
1. 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? (not at all; a little bit; somewhat; quite a bit)	Pattern
Important social, occupational, or recreational activities are given up or reduced because of substance use	
1. 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? (not at all; a little bit; somewhat; quite a bit)	Priority/Harm
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	
1. How much does tobacco currently cause you any physical problems like coughing, difficulty breathing, lung trouble, or problems with your heart or blood pressure? (not at all; a little bit; somewhat; quite a bit)	Harm
2. How much does tobacco currently cause you any emotional problems like irritability, nervousness, restlessness, difficulty concentrating, or depression? (not at all; a little bit; somewhat; quite a bit)	Harm
Dimensions of Tobacco Dependence Scale (DTDS) (43)	
Social reinforcement	
1. Smoking helps me fit in at school	Utility
2. Smoking makes me feel popular	Utility
3. Smoking makes me look cool	Utility
4. Giving cigarettes to my friends makes me feel important	Utility
5. Sharing cigarettes helps me feel closer to other people	Utility
6. Smoking makes me look more mature	Utility
7. Bumming a cigarette makes it easier for me to start a conversation with someone I don't know very well	Utility

Table 1, continued

		Item content category
8.	Smoking helps me feel in control of my life	Utility
9.	I feel more confident when I smoke	Utility
10.	Smoking makes it easy for me to talk to people	Utility
11.	I like the image of me as a smoker	Utility
Emotional reinforcement		
1.	I need to smoke when I am stressed	Trigger
2.	I need to smoke when I am sad or depressed	Trigger
3.	I need to smoke to relax	Trigger
4.	I need a cigarette to calm me down when I am angry	Trigger
5.	I need to smoke when I am nervous	Trigger
	Physical reinforcement	
1.	I need to smoke in between classes	Withdrawal/compulsion
2.	I need to keep my nicotine levels up	Withdrawal/compulsion
3.	My smoking is automatic- I don't even think about it	Unclassifiable
4.	I need to make sure I have enough cigarette to get me through the day	Unclassifiable
5.	My body needs cigarettes to feel right	Withdrawal/compulsion
6.	I can function better after my first cigarette of the day	Utility
7.	My body craves cigarettes when I don't smoke	Withdrawal/compulsion
8.	I like to smoke after I eat	Pattern
9.	I feel panicked when I run out of cigarettes	Unclassifiable
10.	If I don't have a cigarette, I don't know what to do with my hands	Utility
11.	I smoke when I am alone	Pattern
12.	Even when I don't have time for a whole cigarette, I manage to fit in a few drags	Pattern
13.	I smoke in front of my parents	Pattern
14.	I can concentrate better after a cigarette	Utility
15.	I need to smoke when I am hungry	Utility or Trigger
16.	I can go all day without smoking a cigarette	Unclassifiable
17.	I need to smoke when I am bored	Trigger
18.	I need to smoke when I am irritable	Trigger
19.	I find myself looking forward to my next cigarette	Unclassifiable
20.	I plan my activities around my smoking	Unclassifiable
21.	I need to smoke when I am partying	Trigger
22.	I reward myself with a cigarette	Utility
23.	Smoking is one thing in my life that I can control	Withdrawal/compulsion
24.	I find myself smoking for no reason	Unclassifiable
25.	I find myself not wanting to share my cigarettes with others	Attitude
26.	I need to smoke so I won't eat too much	Utility
27.	I find smoking goes with coffee and other drinks	Trigger
Sensory reinforcement		
1.	I smoke but don't really like the taste	Unclassifiable
2.	I like the feeling of blowing out smoke	Utility
3.	Smoking makes things like having a pop or a coffee more enjoyable	Utility
4.	I like the taste of cigarettes	Utility
5.	I enjoy holding and handling cigarettes	Utility
6.	I enjoy the feeling of smoke in my lungs	Utility
ICD-10 Tobacco Dependence (31)		
Strong desire or sense of compulsion to take tobacco		
1.	Have you ever had strong cravings to smoke cigarettes((no; yes)	Withdrawal/compulsion
2.	How physically/mentally addicted to smoking are you? (not at all addicted; a little addicted; quite addicted; very addicted)	Withdrawal/compulsion
3.	How often have you felt like you really need a cigarette? (never; rarely; sometimes; often)	Withdrawal/compulsion
4.	Do you find it difficult not to smoke in places where it's not allowed (at a movie theatre, at home if your parents don't smoke)? (not at all difficult/I don't know; a bit difficult; very difficult)	Unclassifiable

Table 1, continued

	Item content category
Difficulties controlling tobacco taking behavior in terms of onset, termination, or levels of use	
1. In the past 3 months, did you seriously try to quit smoking completely and forever? (yes, I quit completely and have remained non-smoking ever since; I never tried to quit; yes, I tried to quit but failed)	Withdrawal/compulsion
2. Do you smoke cigarettes now because it is really hard to quit? (I don't know/I smoke so little; I don't know because I have never tried to quit; no; sometimes; often/always)	Withdrawal/compulsion
A physiological withdrawal state when tobacco use has ceased or been reduced, as evidenced by: the characteristic withdrawal syndrome for tobacco; or use of the same (or closely related) substance with the intention of relieving or avoiding withdrawal symptoms	
1. How often did you experience the following…? (never; rarely; sometimes; often)	
2. Feeling irritable or angry	Withdrawal/compulsion
3. Feeling restless/feeling nervous, anxious or tense	Withdrawal/compulsion
4. Trouble concentrating	Withdrawal/compulsion
5. Feeling a strong urge or need to smoke	Withdrawal/compulsion
Evidence of tolerance, such that increased doses of tobacco are required in order to achieve effects originally produced by lower doses	
How true are each of the following statements of you?	
1. Compared to when I first started smoking, I need to smoke a lot more now to be satisfied (not a all true; a bit true; very true)	Tolerance
2. Compared to when I first started smoking, I can smoke much more now before I start to feel nauseated or ill (I've never felt nauseated or ill from smoking; not a all true; a bit true; very true)	Tolerance
Progressive neglect of alternative pleasure or interests because of tobacco use, increased amount of time necessary to obtain or take the substance or to recover from its effects	
How true are each of the following statements for you? (not a all true; a bit true; very true)	
1. I spend a lot of time getting cigarettes (going out of my way to a store where I know they will sell to me; trying to find someone who will buy them for me)	Priority
2. I've stopped hanging out with certain people because of my smoking	Priority
3. I avoid going to a friend's house where you're not allowed to smoke even though I might enjoy hanging out with him/her	Priority
4. I have cut down or stopped physical activities or sports because of my smoking	Priority
Persisting with tobacco use despite clear evidence of overtly harmful consequences, such as depressed mood states consequent to periods of heavy substance use, or drug related impairment of cognitive functioning; efforts should be made to determine that the user was actually, or could be expected to be, aware of the nature and extent of the harm	
How true are each of the following statements for you?	
1. In situations where I need to go outside to smoke, it's worth it even in cold or rainy weather (not at all true; a bit true; very true)	Priority
2. If you are sick with a bad cold or sore throat, do you smoke? (no, I don't have to, I smoke so little; no, I stop smoking when I'm sick; yes, but I cut down on the amount I smoke; yes, I smoke the same amount as when I am sick).	Harm
ND/Cravings Symptom Cluster (31)	
1. In the past 3 months, did you seriously try to quit smoking completely and forever? (yes, I quit completely and have remained non-smoking ever since; I never tried to quit; yes, I tried to quit but failed)	Withdrawal/compulsion
2. How often do you have cravings to smoke cigarettes? (never; very rarely; sometimes; often; very often)	Withdrawal/compulsion
3. How physically addicted to smoking cigarettes are you? (not at all; a little; quite; very)	Withdrawal/compulsion
4. How mentally addicted to smoking cigarettes are you? (not at all; a little; quite; very)	Withdrawal/compulsion
5. How often have you felt like you really need a cigarette? (never; very rarely; sometimes; often; very often)	Withdrawal/compulsion
6. Do you find it difficult not to smoke in places where it's not allowed (at a movie theatre, at home if your parents don't know you smoke)? (not at all difficult/don't know; a bit difficult; very difficult)	Unclassifiable
7. If you are sick with a bad cold or sore throat, do you smoke? (no, I don't have to, I smoke so little; no, I stop smoking when I'm sick; yes, but I cut down on the amount I smoke; yes, I smoke the same amount when I am sick)	Pattern/Harm
8 How deeply do you usually inhale the smoke? (into my mouth; into my throat; into my lungs shallow; into my lungs deep)	Pattern
9. How true is the following statement for you? Cigarettes are good for dealing with boredom (not at all true; a bit true; very true)	Utility

Table 1, continued

		Item content category
10.	Do you smoke cigarettes now because it is really hard to quit? (I don't know/I smoke so little/I quit; no, it is not hard to quit; never tried to quit/I don't want to quit; yes (sometimes, often/always))	Withdrawal/compulsion
11.	On the days that you smoke, when do you usually smoke your first cigarette of the day? (right when I wake up; in the morning; later or another time)	Pattern
	How true are each of the following statements for you? (not at all true; a bit true; very true)	
12.	I often run out of cigarettes quicker than I thought I would	Unclassifiable
13.	I spend a lot of time getting cigarettes (going out of my way to a store where I know they will sell to me; trying to find someone who will buy them for me)	Priority
14.	I spend a lot of time smoking cigarettes (chain smoking, smoking a lot throughout the day)	Pattern
15.	When you see other kids in your age smoking cigarettes, how easy is it for you not to smoke? (very easy; quite easy; a bit difficult; very difficult)	Trigger
16.	How often do you smoke cigarettes when you are alone? (never; sometime; often/always)	Pattern
Nicotine Dependence Syndrome Scale (NDSS)*		
How well do each of the following statements describe you? (not at all true; somewhat true; moderately true; very true; extremely true)		
1.	After not smoking for a while, I need to smoke to relieve feelings of restlessness and irritability.	Withdrawal/compulsion
2.	Whenever I go without a smoke for a few hours, I experience craving.	Withdrawal/compulsion
3.	When I'm really craving a cigarette, it feels like I'm in the grip of some unknown force that I cannot control.	Unclassifiable
4.	After not smoking for a while, I need to smoke in order to keep myself from experiencing any discomfort.	Withdrawal/compulsion
5.	I tend to avoid restaurants that don't allow smoking, even if I would otherwise enjoy the food.	Priority
6.	Even if traveling a long distance, I'd rather not travel by airplane, because I wouldn't be allowed to smoke.	Priority
7.	Sometimes I decline offers to visit with my non-smoking friends because I know I'll feel uncomfortable if I smoke.	Attitude
8.	If you couldn't get ahold of any cigarettes for a whole day, how much would you be willing to pay by the next morning for just one cigarette? ($ amount)	Priority
9.	Compared to when I first started smoking, I need to smoke a lot more now in order to really get what I want out of it.	Tolerance
10.	Compared to when I first started smoking, I can smoke much, much more now before I start to feel nauseated or ill.	Tolerance
11.	Since the time when I became a regular smoker, the amount I smoke has either stayed the same or has decreased somewhat.	Tolerance or Pattern
12.	My smoking pattern is very irregular throughout the day. It is not unusual for me to smoke many cigarettes in an hour, then not have another one until hours later.	Pattern
13.	Sometimes, without realizing it, I go for several hours or more without smoking.	Unclassifiable
14.	I smoke just about the same number of cigarettes from day to day.	Pattern
15.	My smoking is not much affected by other things. I smoke about the same amount whether I'm relaxing or working, happy or sad, alone or with others, etc.	Pattern
16.	Not even a torrential rainstorm could stop me – if I were out of cigarettes, I would be immediately on my way to the store to get some more.	Priority
17.	Where regulations require that I go outdoors to smoke, it's worth it to be able to smoke a cigarette, even in cold or rainy weather.	Priority
18.	If I wake up during the night, I feel I need a cigarette.	Withdrawal/compulsion
19.	I can function much better in the morning after I've had a cigarette.	Utility
20.	I feel a sense of control over my smoking. I can "take it or leave it" at any time.	Unclassifiable
21.	Sometimes even when I'm telling myself I'm not going to have a cigarette, I find myself smoking anyway.	Unclassifiable
22.	Whenever I quit or cut down on smoking, it is an unpleasant experience.	Unclassifiable
23.	The last time I quit (for 24 hours or more), when I went back to smoking it took a long time for me to build up to my old level of smoking.	Unclassifiable
III. SCALES THAT DO NOT MEASURE WITHDRAWAL/COMPULSION		
Fagerström Test for Nicotine Dependence (FTND) (60)		
1.	How soon after you wake up do you usually smoke your first cigarette?	Pattern

Table 1, continued

		Item content category
2.	Which cigarette would you most hate to give up?	Pattern
3.	Do you smoke more during the first hours after waking than during the rest of the day?	Pattern
4.	Do you find it difficult to refrain from smoking in places where it is forbidden?	Unclassifiable
5.	During the past 30 days, on the days you smoked, how many cigarettes did you smoke per day?	Pattern
6.	Do you smoke if you are so ill that you are in bed most of the day?	Pattern/Harm
Modified Fagerström Tolerance Questionnaire (mFTQ) (61)		
1.	How many cigarettes a day do you smoke? (less than 1; 1-15; 16-25; more than 25)	Pattern
2.	Do you inhale? (never; sometimes; always)	Unclassifiable
3.	Do you smoke more during the first 2 hours of the day than during the rest of the day? (no; yes)	Pattern
4.	How soon after you wake up do you smoke your first cigarette? (less than 30 minutes; more than 30 minutes but before noon; in the afternoon or evening)	Pattern
5.	Which cigarette would you hate to give up? (first one in the morning; any other before noon; any other in the afternoon or in the evening)	Pattern
6.	Do you find it difficult to refrain from smoking in places where it is forbidden? (no; yes)	Unclassifiable
7.	Do you smoke if you are so ill that you are in bed most of the day? (no; yes)	Pattern/Harm
Stanford Dependence Index (SDI) (62)		
1.	When you are in a place where smoking is forbidden, is it difficult for you not to smoke (very difficult; difficult, somewhat difficult; slightly difficult; not at all difficult)	Unclassifiable
2.	Do you smoke more in the morning than during the rest of the day? (always; usually; sometimes; rarely; never)	Pattern
3.	Do you smoke even when you are really sick (for example, coughing or vomiting a lot)? (always; usually; sometimes; rarely; never)	Pattern/Harm
4.	How deeply do you inhale the smoke? (just in to the mouth; as far back as the throat; partly into the chest; deeply into the chest)	Pattern
5.	How soon after you wake up in the morning do you smoke your first cigarette? (when I first open my eyes; within the first 15 minutes; between 15 and 30 minutes; between 30 and 60 minutes; between 1 and 2 hours; more than 2 hours)	Pattern
Nicotine Dependence Scale for Adolescents (NDSA) (52)		
1.	Do you think you would be able to quit smoking if you wanted to? (I don't smoke now; definitely yes; probably yes; probably not; definitely not)	Unclassifiable
2.	How soon after you wake up do you usually smoke your first cigarette? (I don't smoke now; less than 15 minutes; 15 to 30 minutes; more than 30 but less than 60 minutes; 1 to 2 hours; more than 2 hours but less than half a day; more than half a day; I don't smoke during the weekdays)	Pattern
3.	If you are sick with a bad cold or a sore throat, do you smoke cigarettes? (I don't smoke now; no, I stop smoking when I am sick; yes, but I cut down on the amount that I smoke; yes, I smoke the same amount as when I'm not sick).	Pattern/Harm
4.	How true is this statement for you? When I go without a smoke for a few hours, I experience craving (I don't smoke now; not at all true; not very true; fairly true; very true).	Withdrawal/compulsion
5.	How true is this statement for you? I sometimes have strong cravings where it feels like I'm in the grip of a force that I cannot control (I don't smoke now; not at all true; not very true; fairly true; very true).	Unclassifiable
Self -Medication Symptom Cluster (31)		
How true are each of the following statements for you? (not at all true; a bit true; very true)		
1.	I can function much better in the morning after I've had a cigarette.	Utility
2.	When I'm feeling down, a cigarette makes me feel good.	Utility
3.	A cigarette gives me energy when I'm tired.	Utility
4.	Smoking cigarettes calms me down when I feel nervous.	Utility
5.	Smoking cigarettes helps me concentrate on my homework.	Utility
6.	Smoking cigarettes relieves tension when I am stressed.	Utility

*A youth-specific version of the NDSS exists, but it was not possible to obtain a copy of the scale and its items.

Table 2
Summary of articles that assess psychometric properties of measures of nicotine dependence for adolescents

Reference	Scale	Study population	Psychometric properties	Association with smoking behavior
DiFranza et al. (26)	AUTOS	Grade 10 and 11 students	Internal consistency α=0.96; Inter-item Correlation range=0.51-0.87	Number of ND symptoms endorsed (ρ=0.69) and symptom intensity (ρ=0.62) correlated with daily cigarette consumption. More experience with smoking was associated with a greater likelihood of endorsing each item. AUTOS was associated with age at smoking initiation and failed quit attempts.
Dierker et al. (38)	DSM-IV	n=859 smokers In first year college	Internal consistency for 7 dependence criteria (KR-21): tolerance (2 items) = 0.90–0.91, withdrawal (8 items) =0.89–0.90, smoking in larger amounts or longer than intended (2 items) = both 0.90, persistent desire or unsuccessful efforts to cut down (1 item) = 0.90, Great deal of time spent to obtain, use or recover from smoking (1 item) = 0.91, activities given up or reduced (1 item) =0.91, and smoking despite physical or psychological problems (2 items) = 0.90–0.91.	There was a moderate association between past week smoking quantity and ND. A positive linear effect was seen in the association between frequ-ency of past week smoking and ND prevalence (β = 1.95, p < 0.001).
Rose and Dierker (40)	DSM-IV	n=2758 recent onset smokers in a nationally representative sample of adolescents	Exploratory factor analysis indicated a single latent factor.	DSM-IV symptoms were invariant across nonda ily and daily smokers.
Johnson et al. (43)	DTDS (54-items)	n=562 students who had smoked in past month	Social reinforcement α=0.89; emotional reinforcement α= 0.90; sensory reinforcement α=0.72; physical reinforce-ment α=0.96; Compares to α=0.87 for HONC and α= 0.68 for FTQ	Physical and emotional reinforcements were strongly correlated with HONC (r=0.78, and r=0.67, respectively), FTQ (r=0.74 and r=0.55, respectively), and self-reported addiction (r=0.75 and r=0.61). The emotional and physical reinforcement subscales were significantly associated with amount smoked in the past week and past-year number of cessation attempts.
Richardson et al. (63)	DTDS (36 items)	n=1425 past-month smokers (mean age 16 years)	Social dependence α=0.91; emotional dependence α= 0.92; ND α=0.97; sensory dependence α=0.80	All DTDS dimension scores had significant correlations with existing measures of tobacco dependence, cigarette smoking and self-reported addiction.
Lu et al. (41)	DTDS (49 items)	n=293 male smokers aged 15-18 in Taiwan	DTDS scale: α=0.94. Exploratory factor analysis confirmed 4 subscales. Physical reinforcement α= 0.94; social reinforcement α=0.87; emotional reinfor-cement α=0.89; sensory reinforcement α=0.67	DTDS correlated with the FTND (r =0.58) and saliva cotinine level (r =0.30).
Nonnemaker and Homsi (50)	FTND	n=907 smokers in US high-schools	In 2-factor solution, correlation between 2 factors= 0.92 providing support for single a	

Table 2, continued

Reference	Scale	Study population	Psychometric properties	Association with smoking behavior
			factor model. Reliability for single-factor model α=0.75. Reliability of a 2-factor model α=0.66 for factor 1, α=0.58 for factor 2	
DiFranza et al. (29)	HONC	n=332 past-month smokers in grade 7	Factor analysis indicated a single-factor. Internal consistency α=0.94	HONC correlated with maximum amount smoked (*r*=0.65) and maximum frequency of smoking (*r*=0.79), r=.18 for duration of tobacco use, and r= −0.11 for age at first use. Among monthly smokers, correlations were r=0.53 for maximum amount smoked, r=0.57 for maximum frequency of smoking, and r=0.18 for duration of tobacco use. Endorsement of a single item on the HONC was associated with a failed attempt at smoking cessation (OR= 29; 95% CI, 13-65), continued smoking (OR= 44; 95% CI, 17-114), and daily smoking (OR= 58; 95% CI, 24-142).
O'Loughlin et al. (64)	HONC	n=64 high-school student smokers aged 14-17	Not applicable	Focus group participants understood the items and identified with the symptoms.
Wheeler et al. (28)	HONC	n=88 grade 9 students who had puffed on a cigarette	Internal consistency α=0.90; test retest reliability ICC=0.88; reliability over time median Yules' Y=0.71, range =0.41-0.82	HONC scores correlated with smoking frequency (r=0.70).
Huang et al. (33)	HONC (Chinese version)	n=373 male smokers aged 15-20 in Taiwan	Most HONC inter-item correlations ranged from .3-7 (inter-item correlations for item 1 were lower). Each item is highly associated with the full scale (r>0.7), except item 1. Internal reliability α=0.83	Each HONC item and the total score are significantly associated with FTND (r=0.21-0.59, and r=0.58, respectively). Each HONC item, except item 8, and total score are significantly associated with saliva cotinine level (r=0.11-0.44, and r=0.27, respectively).
Wellman et al. (30)	HONC	n=300 college students who were current smokers	Internal consistency α=0.89	After controlling for smoking frequency, the HONC was predictive of the likelihood of a failed cessation attempt, with each additional symptom doubling the likelihood.
O'Loughlin et al. (31)	ICD-10	n=233 grade 7 students who smoked in past 3 months	Internal consistency α=0.91. Test-retest reliability ICC=0.49	ICD-10 score increased with increased exposure to tobacco. ICD-10 demonstrated convergent construct Validity against quit attempts and smoking status.
Wellman et al. (32)	mFTQ	n=215 participants aged 14-20 who smoked in past month	Inter-item correlations low to moderate (range=0.14-0.68). Internal consistency α=0.83. Stability over follow-up ICC=0.79 at 6-month follow-up and ICC=0.76 at 12-months	The mFTQ (minus the item on smoking frequency) correlated with smoking frequency (r=0.70). mFTQ predicted smoking cessation outcomes at 6-, but not 12-months.

Table 2, continued

Reference	Scale	Study population	Psychometric properties	Association with smoking behavior
Fernando et al. (15)	LTW	Representative national sample of 3792 current smokers aged 9-21	Single item measure	LTW correlated negatively with smoking frequency (r=-0.53) among 2,350 youth who smoked <6 cigarettes per day, and r= -0.23 745 youth who smoked >=6 cigarettes daily.
DiFranza and Ursprung (4)	LTW	Students aged 16-19	Single item measure	LTW correlated negatively with smoking frequency (Kendall's tau b= -0.53), age at smoking initiation (b= -0.25), duration of tobacco use (b=-0.25), and a withdrawal symptom score (b=-0.44).
Chen et al. (51)	mFTQ	n=48 grade 10 students in China who were past 30 day smokers	Two different item scoring protocols (original scoring-Protocol A and modified scoring Protocol B) were used. Two versions of the mFTQ were compared: original 7 items and 4-item version. For 7-item version: Protocol A α= 0.42; Protocol A α= 0.67; For 4-item version: Protocol A α=0.63; Protocol A α= 0.79	Principal-component analysis indicated 3 factors under Protocol A and 2 factors under Protocol B. Total mFTQ scores (Protocols A & B and both 7-item and 4-item versions) were significantly associated with self-reported smoking and saliva cotinine levels.
Nonnemaker et al. (52)	NDSA	n=4909 students who were current smokers	Exploratory and confirmatory factor analyses indicated 1 factor. Cronbach's α for NDSA scale was 0.81	NDSA correlated with lifetime number of cigarettes smoked (r=0.44), days smoked in past 30 days (r=0.66), cigarettes smoked per day on days smoked (r=0.61), number of quit attempts (r=010), and correlated negatively with length of quit attempt (r=-0.22).
Sterling et al. (45)	Youth-specific NDSS	n=526 student past-month smokers	NDSS Total Score: internal consistency α=0.94; test-retest reliability 0.72; Drive α=0.92; test-retest reliability 0.67. Tolerance α=0.85; test-retest reliability 0.65. Priority: α=0.83; test-retest reliability: 0.65. Stereotypy: α=0.73; test-retest reliability: 0.43. Continuity: α=0.64; est-retest reliability: 0.46	NDSS-Total, drive, tolerance, and priority predicted amount smoked. Drive, tolerance, and continuity predicted cessation. Neither NDSS-Total nor any of its subscales predicted number of days smoked.
Costello et al. (47)	NDSS	n=154 light smokers in first-year college	Drive: α=0.83; Priority: α=0.91; Stereotypy: α=0.60; Continuity: α=0.82; Tolerance: α=0.88 Confirmatory factor analysis supported a 5-factor model	A second-order factor model did not fit the data as well as the correlated first order factor model. An overarching dependence factor may not account for the interrelationships among the 5 first-order factors.
Dierker and Mermelstein (48)	NDSS (youth version reduce ed to 10 items)	n=746 students in grades 9 and 10	Shortened youth version of NDSS α=0.93	For those who smoked <100 cigarettes, NDSS total score at baseline predicted past week smoking (OR = 2.4 (1.4-4.0)) and daily smoking (OR = 2.2 (1.1-4.5)) at 24 months

Table 2, continued

Reference	Scale	Study population	Psychometric properties	Association with smoking behavior
O'Loughlin et al. (31)	Three symptom clusters ncluding ND/cravings; withdrawal; self-medication	n=233 grade 7 students who smoked in past 3 months	ND/craving cluster α=0.94; test-retest reliability ICC=0.91. Withdrawal symptom cluster α=0.88; test-retest reliability ICC=0.78. Self-medication symptom cluster α=0.85; test-retest reliability ICC=0.74	Scores for the 3 symptom clusters increased with increased exposure to tobacco and need to smoke more to feel satisfied. All 3 demonstrated convergent construct validity against quit attempts and smoking status
O'Loughlin et al. (36)	SDI	n=66 smokers aged 14-17 who smoked in past 3 months	SDI: α=0.78; test-retest reliability ICC=0.78. ICC for 5 SDI items ranged from 0.71-0.77	Mean SDI score was 10.2 (4.2) for past 3-month smokers, 7.7 (2.8) for those who smoked ≤8 cigarettes/week, 12.6 (3.9) among those who smoked >8 cigarettes/week. All SDI items were related to smoking intensity and failed quit attempts. SDI was associated with the HONC.

Table 3
Summary of articles that compare measures of nicotine dependence in adolescents

Reference	Scales compared	Study population	Reliability	Cross structure analysis
O'Loughlin, et al. (31)	HONC, ICD-10, ND/cravings symptom luster; withdrawal symptom cluster; self-medication symptom cluster	n=233 grade 7 students who smoked in past 3 months	HONC internal consistency α=0.87; test-retest reliability ICC=0.81. ICD-10 internal consistency α= .91; test-retest reliability ICC=0.49. ND/cravings symptom cluster internal consistency α= 0.94; test-retest reliability ICC=0.91. Withdrawal symptom cluster internal consistency α=0.88; test-retest reliability. ICC=0.78. Self-medication symptom cluster internal consistency α= .85; test-retest reliability ICC=0.74	Scores for the 5 indicators increased with increased exposure to tobacco. All 5 indicators demonstrated convergent construct validity against quit attempts and smoking status. The 5 indicators were inter-correlated (r=0.72-0.91)
O'Loughlin, et al. (36)	HONC, SDI	n=66 smokers aged 14-17 years who smoked in past 3 months	HONC α=0 .90. Test-retest reliability good to excellent (range κ= 0.61-0.93). SDI α=0.78; ICC for 5 SDI items ranged from 0.71-0.77. SDI score showed good test-retest reliability (ICC=0.78).	Convergent construct validity against number of cigarettes smoked per week (≤8 versus >8) was demonstrated for HONC, SDI. HONC symptoms were associated with failed quit attempts and increased number of cigarettes smoked per week. SDI was significantly associated with HONC. SDI items also related as expected with failed quit attempts.
Wellman et al. (32)	HONC, mFTQ	n=215 participants aged 14-20 in a smoking cessation study who had smoked in past month	HONC: α= 0.92. Inter-item correlations, range= 0.40-0.73. Stability over follow-up interval: ICC=0.93 at 6-month follow-up and ICC=0.91 at 12-month follow-up. mFTQ: α= 0.83. Inter-item correlations, range= 0.14-0.68. Stability over follow-up interval: ICC=0.79 at 6-month follow-up and ICC=0.76 at 12-month follow-up	Correlation between baseline HONC and mFTQ was high (r=0.83). HONC and mFTQ at baseline correlated similarly with number of cigarettes consumed on smoking days (HONC: r= 0.69; mFTQ (minus item 1): r= 0.70). HONC predicted cessation outcomes at 6- and 12-month follow-up, while mFTQ predicted outcomes at 6-month follow-up only

Table 3, continued

Reference	Scales compared	Study population	Reliability	Cross structure analysis
MacPherson et al. (34)	HONC, mFTQ	n=109 adolescents aged 14-18 who had smoked in past 30 days, participating in smoking cessation self-change	HONC: α=0.89 mFTQ: α=0.62	HONC and mFTQ items could be linked to a single latent construct. Most HONC items captured variability at the lower range and the mFTQ items made discriminations at the middle and higher end of the underlying construct. The mFTQ lacks sensitivity for assessing ND across the full range of adolescent tobacco use.
Kandel et al. (53)	mFTQ, DSM-IV	15,007 grade 6-10 students who had ever smoked.	DSM-IV α= 0.83. Mean item-total correlation r= 0.58. Mean inter-item correlation = 0.41. mFTQ α= 0.72. Mean item-total correlation r= 0.43. Mean inter-item correlation = 0.26. Correlation between two scales r=0.67 among lifetime smokers and r= 0.56 among last 30-day smokers. Concordance between scales as dichotomous measures of dependence: κ= 0.34 among lifetime smokers and κ= 0.29 among past 30-day smokers.	DSM-IV identified more ND smokers than mFTQ: (24% vs. 9% among lifetime smokers; 87% vs. 63% among those smoking >=20 of last 30 days. ND increased with daily number of cigarettes smoked, and was uniformly higher on the DSM-IV than mFTQ. Tolerance, withdrawal, and impaired control symptoms were endorsed more than any other symptom by those who were dependent on both the mFTQ and the DSM-IV scales. While both measures claim to identify ND individuals, neither includes a preponderance of items measuring ND and the two measures disagree with one another regarding who is dependent.
Strong et al. (37)	mFTQ, NDSS, DSM-IV	Grade 6-10 students who had smoked in past 30 days (n=253, 241, and 296 in waves 1, 2, and 3, respectively)	mFTQ had high internal consistency at each follow-up (average α=0.90). NDSS average α=0.90. DSM-IV average α=0.70.	Exploratory factor analysis suggests single factor for DSM-IV, mFTQ, and NDSS. DSM-IV and mFTQ had significant overlap in assessing individuals above the traditional DSM diagnostic thresholds. The NDSS provided items more suitable for individuals below DSM diagnostic thresholds. When combining items from these 3 instruments into single instrument, a level of information was achieved that exceeded any one instrument alone.
Kleinjan et al. (35)	HONC, mFTQ, instrument combining HONC and mFTQ	n=2041 secondary school students who smoked in past month	mFTQ α= 0.73; inter-item correlation range= 0.05-0.67; mean = -0.31. Item-total score correlation ranged from 0.27-0.69. Exploratory factor analysis indicated a single-factor solution for mFTQ. HONC α= 0.88; inter-item correlation range= 0.08-0.70, except item 4. Mean inter-item correlation without item 4 was .48 (=0.40 including item 4). Item-total score correlation (excluding item 4) ranged from 0.48-0.77.	Convergent construct validity examined for 17-item instrument combining mFTQ and HONC only. SEM used to determine if 3 factors identified correlated with motivation to quit and number of attempts to quit. All paths were significant with 2 exceptions: a) behavioral aspect of ND were not associated with the number of quit attempts, and b) nervousness was not associated with motivation to quit.

Table 3, continued

Reference	Scales compared	Study population	Reliability	Cross structure analysis
			Exploratory factor analysis indicated a 2-factor solution for HONC. 17-item instrument combining mFTQ and HONC α= .84. Exploratory factor analysis indicated a 3-factor solution (behavioral aspect of ND, craving, nervousness during abstinence)	
DiFranza et al. (26)	AUTOS, HONC, DSM-IV	Grade 10 and 11 students		The AUTOS score correlated with HONC (r=0.81) and number of DSM-IV criteria (r=0.68).
Costello et al. (47)	DSM-IV, FTND, HONC, NDSS	First year college students reporting light smoking patterns	Reliability: DSM-IV α= 0.75; FTND α= 0.59; HONC α= 0.88; NDSS α= 0.82-0.95 for total score and scales, except stereotypy (α= 0.69)	Higher levels of ND measured by HONC and DSM-IV predicted continued smoking, smoking quantity and smoking frequency. DSM-IV, NDSS-priority, and HONC measures provided evidence for incremental validity. Higher scores on all 4 measures were related to shorter lengths of smoking abstinence.

alyses to date supporting the 7-subscale structure [39, 40]. The DSM-IV may be a more accurate indicator among smokers with moderately high levels of ND, than among those with lower ND levels [37].

The Dimensions of Tobacco Dependence Scale (DTDS) is a 51-item measure developed to assess four ND dimensions including social reinforcement, emotional reinforcement, sensory reinforcement, and physical reinforcement. Five of the 51 items measured withdrawal/compulsion. One study using exploratory factor analysis supported a 4-factor structure [41,42]. Internal consistency of the four subscales ranged from 0.67–0.72 (sensory reinforcement) to 0.94–0.96 (physical reinforcement). The DTDS was associated with saliva cotinine, amount smoked in the preceding week, and number of quit attempts in the past year [41,43]. However, the results depended to some extent on whether the DTDS was scored as a single measure or as four subscales, with emotional and physical reinforcement having the strongest associations with behavior [43].

The ICD-10 measure was developed for use in the NDIT Study [31]. It includes 18 items which assess the six ICD-10 criteria for tobacco dependence. Nine of the 18 items measure withdrawal/compulsion. In NDIT [31], the internal consistency of this measure was 0.91, test-retest reliability was 0.49, and convergent construct validity was demonstrated against quit attempts [44]. We found no published reports on the internal factor structure of the ICD-10 [31].

Six of 16 items in the ND/Cravings Symptom Cluster scale measure withdrawal/compulsion [45]. Internal consistency ($\alpha = 0.94$) and test-retest reliability (ICC $= 0.78$) of this scale as measured in the NDIT Study were moderate to high. Scores increased with increased exposure to tobacco and showed convergent construct validity against quit attempts. To date, no other study has reported the reliability or validity of this scale.

Similar to the original Nicotine Dependence Syndrome Scale (NDSS), the youth NDSS assesses drive, priority, stereotypy, continuity, and tolerance [45]. Priority, tolerance, stereotypy and continuity are not unambiguous indicators of ND according to our conceptualization of ND. Only 4–5 of the 23 NDSS items measure withdrawal/compulsion. Although the item "When I'm really craving a cigarette, it feels like I'm in the grip of some unknown force that I cannot control" relates to ND, this item might generate false negative responses from individuals who experience cravings, but do not feel in the grip of an uncontrollable force. Internal consistency of the NDSS was high overall ($\alpha = 0.94$); it ranged from poor/moderate to excellent across dimensions, with stereotypy and continuity demonstrating relatively weaker internal consistency [45,46]. Two studies revealed that high drive, tolerance and priority predicted the amount smoked; drive, tolerance and continuity predicted the cessation [37]. Strong et al. [39] reported a single latent construct. Costello et al. [47] suggested a 5-factor model in confirmatory factor analysis, but a second-order factor model did not fit the data [37,47]. Dierker and Mermelstein [48] presented that the youth version of NDSS

shortened to 10 items predicted smoking status at 24-month follow-up among adolescents who had smoked less than 100 cigarettes.

3.3. Scales that do not measure withdrawal/compulsion

The Fagerström Test for Nicotine Dependence (FTND) is a modified version of the Fagerström Tolerance Questionnaire [49]. Based on our categorization scheme, none of the six items that comprise the scale measure withdrawal/compulsion. The reliability of the FTND was 0.75 in a single-factor model. In a 2-factor model, the reliability was 0.66 for factor 1 and 0.58 for factor 2 [50]. Both the single- and 2-factor models achieved acceptable fit criteria, although the high correlation between the two factors in the 2-factor model argues for a single-factor model. Reliability of the scale was low in a sample of college students ($\alpha = 0.59$) [46].

The Modified Fagerström Tolerance Questionnaire (mFTQ) is a 7-item modification of the FTND for adolescents. None of the seven items measure withdrawal/compulsion. Exploratory factor analysis supports a single-factor structure [32,37]. The mFTQ has variable internal consistency ($\alpha = 0.62$–0.90) across studies, and moderate test-retest reliability (ICC = 0.76–0.79) [37,43]. Compared to other measures (e.g., the HONC), the mFTQ items show poorer discrimination at lower levels of ND [32]. The mFTQ was associated with smoking frequency and predicted cessation at 6-, but not 12-month follow-up [36,43]. It was also associated with self-reported smoking and saliva cotinine levels [51].

The Stanford Dependence Index (SDI) comprises five items, none of which measure withdrawal/compulsion. In one study [36], the SDI had moderate internal consistency ($\alpha = 0.78$) and test-retest reliability (ICC = 0.78), and it demonstrated convergent construct validity against smoking intensity and failed quit attempts [52].

Only one of the five items in the Nicotine Dependence Scale for Adolescents (NDSA), "When I go without a smoke for a few hours, I experience craving," measures withdrawal/compulsion. Since persons who are ND may express confidence in their ability to quit, the item "Do you think you would be able to quit smoking if you wanted to?" may elicit false negative responses as an ND indicator. Exploratory and confirmatory factor analyses supported a single-factor structure [52]. Internal consistency of the scale was moderate ($\alpha = 0.81$), and the NDSA correlated positively with smoking intensity and number of quit attempts. It correlated negatively with length of quit attempt.

None of the six items in the Self-Medication Symptom Cluster measure withdrawal/compulsion. Internal consistency ($\alpha = 0.85$) and test-retest reliability (ICC = 0.74) of this scale were moderate in the NDIT Study. Scores on the scale increased with increased exposure to tobacco and were associated with quit attempts [31]. To date, no other study has reported the reliability or validity of this scale.

3.4. Comparison across measures

In head to head comparisons, the HONC performed better than the mFTQ in three studies and better than the SDI in one study (Table 3). The DSM-IV and the mFTQ are both used to identify individuals with ND, but they have little overlapping content. In a sample of youth who smoked on at least 20 of the last 30 days, the prevalence of ND was 87% as measured by the DSM-IV and 63% as measured by the mFTQ [53].

4. Discussion

ND is a recognized medical condition related to a physiologic dependence on nicotine that produces a compulsion to smoke [2]. The core clinical features of ND are symptoms of withdrawal (i.e., wanting, craving, needing) and shortening of the latency to withdrawal [4,15]. No single measure to date captures all these features. Among the 14 measures reviewed, three (HONC, LTW, Withdrawal Symptom Cluster) include items that measure these core clinical features. In the past decade, the HONC was the most frequently assessed and widely used (in 14 languages) ND measure in youth. It offers broad coverage of the core clinical features of ND, but it does not assess wanting or latency. The Withdrawal Symptom Cluster and LTW measures each cover only one aspect of ND. The LTW measure has performed well in both adults and adolescents [7] and is currently undergoing further evaluation in English, Spanish, French and Dutch. The Withdrawal Symptom Cluster has not been used widely, but offers response choices on a Likert type scale that may be more amenable to discriminating levels or severity of ND. The remaining 11 measures reviewed do not assess ND directly. Rather, several include some ND items, but also evaluate a wide variety of other aspects of smoking behavior that may indirectly reflect

ND to a greater or lesser degree, including attitudes, harm, prioritization, smoking patterns, tolerance, triggers, and utility. Five measures (FTND, mFTQ, NDSA, Self-Medication Symptom Cluster, SDI) had few or no indicators of withdrawal or compulsion to use tobacco.

Selection of items into a measure can be based on alignment with theory, substantive or content validity (i.e., the item appears to tap into the construct that the researcher wishes to measure), and/or statistical performance in psychometric analyses. The criteria used to select items into some of the ND measures reviewed herein were sometimes not apparent. Many items may be based on the DSM or ICD conceptualizations of ND, although recent systematic reviews suggest that DSM and ICD criteria for ND have not been fully validated and in addition, have little or no theoretical or clinical foundation [44,54].

4.1. Alignment with theory

Colby et al. called for theory based measures [1]. Only three of the 14 measures reviewed were developed based on theory including the AUTOS, HONC, and LTW. Specifically they derive from the Autonomy Theory that states that dependence begins when the use of tobacco results in the appearance of symptoms that present a barrier to discontinuing tobacco use [55]. All items in these three measures have face validity as obstacles to cessation or evidence of failed cessation. Mechanistically, these measures are all tied to the Sensitization-Homeostasis Theory which addresses the clinical course of ND and how nicotine triggers dependence [56]. Each of these measures was derived as a research tool for a specific purpose, the HONC to identify the first symptoms of addiction, the AUTOS to compare the development and resolution of physical dependence, cue-induced craving, and psychological reliance on smoking as separate mechanisms of addiction, and the LTW to measure the change in LTW over the trajectory of addiction. Each of these measures has been successfully used to test these theories [4,26,56].

4.2. Substantive or content validity

While many behaviors covered in the ND measures reviewed are manifestations of physiologic dependence and the accompanying compulsion to use tobacco, they may not be accurate or diagnostic ND indicators. In addition, the direct approach to symptom assessment used in clinical practice is often abandoned in scale development to camouflage the intent of the item from subjects. Both these issues may result in items that can be endorsed for reasons other than ND. For example, some youth who violate school smoking policies do not have ND [57]. A person might find it difficult to refrain from smoking where it is prohibited because they enjoy breaking the rules. Other items may not be endorsed by addicted smokers if they describe situations that do not apply to them because they are not daily smokers or do not have permission to smoke. Such items may generate false negative responses and lack sensitivity.

The requirements for an ND measure may differ depending on whether the measure is used for research or for diagnostic purposes. Medical disorders such as ND are diagnosed by identifying an aberration of normal physiology, and a diagnosis is made when signs or symptoms allow the diagnostician to identify the disorder and distinguish it from others [2]. Many disorders can be diagnosed when they are mild or asymptomatic. The diagnosis of ND is based on the presence of its recognized clinical features and does not require assessment of symptom severity, self injury, or disability. In contrast, understanding of severity may be helpful to researchers studying the very early onset of ND, when prevention of progression to fully established ND is still relevant.

4.3. Statistical performance in psychometric analyses

Identification of a factor in factor analysis of an ND measure does not necessarily identify it as an ND domain. Factor analysis identifies clusters of correlated items endorsed by the same subject, and the number of factors identified depends on how many different content areas are covered by the items in the measure. Items that assess behaviors unrelated to dependence (e.g., smoking to be popular) can be identified in a factor analysis of items in an ND measure.

In order to develop a scale with good discrimination at all levels of ND severity, statistical methods such as Item Response Theory have been used to evaluate combinations of measures such as the mFTQ with the HONC, or the mFTQ, NDSS, and DSM-IV [34,35, 39]. Such exercises produce ad hoc scales based on the mathematical science of scale development rather than medical science applied to the assessment of a biological condition. The resulting ad hoc scales are not derived from addiction theory or from the known pathophysiology of nicotine dependence. In an effort to evaluate comparative severity, IRT analysis is used to plot individual items in relation to a “common latent

continuum" that is generated by the collective items selected for inclusion in the analysis [37]. Just as factors in a factor analysis do not define clinically relevant domains of addiction, a latent continuum generated from a collection of survey items does not define the continuum of ND. The continuum of ND is manifested in the progressive intensification of withdrawal symptoms (wanting, craving, needing) and the shortening of the latency to withdrawal [2].

5. Conclusions and recommendations

Of ND measures available for adolescents, the HONC likely provides the best single-measure coverage of the core clinical features of ND and in addition, it has had the most extensive assessment of validity and reliability. Combining the HONC and LTW measures may provide comprehensive coverage of the recognized clinical features of ND. Instruments that do not measure ND may nevertheless be useful in research, since ND is not the only feature of smoking behavior that warrants investigation. Researchers should be cognizant of what the ND measure selected actually measures, and assure that its content aligns closely with their research objectives.

5.1. Recommendations

1. Researchers should limit use of the term "measure of ND" to those measures that assess clinically recognized features of ND [2].
2. ND typically begins prior to the onset of daily smoking. Since adolescents who are early in the smoking onset process often smoke infrequently and sporadically, items that assess patterns of daily smoking will likely show differential item functioning when used across the full spectrum of adolescent and adult tobacco use. ND measures should be applicable across the wide spectrum of exposure among adolescents at all levels of smoking.
3. Youth do not have unfettered access to tobacco and cannot smoke at all times of the day or when sick in bed. Items alluding to the timing of smoking or access to cigarettes will therefore not measure ND unambiguously.
4. Psychometric evaluation must include the full spectrum of adolescent smokers and not be limited to daily smokers or those in cessation programs.
5. The clinical features of ND are the same in adolescents and adults [2,16]. If a measure assesses symptoms rather than behaviors associated with those symptoms, it can be used in smokers of all ages and at all levels of use. The HONC, the AUTOS, and the Latency to Withdrawal have the same performance characteristics in adults and adolescents at all levels of tobacco use [15,26,58].
6. At this point in time, the validity of an ND measure can only be assessed by comparing its content to the recognized clinical features of ND. Smoking frequency and cotinine levels do not measure ND and therefore, cannot validate an ND measure. Similarly, the ability to predict cessation outcomes is not proof that a scale measures ND, and finally the validity of an ND measure cannot be established by demonstrating a correlation with scales that do not themselves measure ND. Factors completely unrelated to ND, such as church attendance, can predict smoking cessation outcomes better than some ND measures [59].

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