Drug and Alcohol Dependence 142 (2014) 333–340

Contents lists available at ScienceDirect

Drug and Alcohol Dependence

journal homepage: www.elsevier.com/locate/drugalcdep

What is the evidence for hardening in the cigarette smoking population? Trends in nicotine dependence in the U.S., 2002–2012☆

Philip H. Smith[a,c,*], Jennifer S. Rose[b], Carolyn M. Mazure[a,c], Gary A. Giovino[d], Sherry A. McKee[a,c]

[a] Department of Psychiatry, Yale University, 2 Church Street South, Suite 109, New Haven, CT 06519, United States
[b] Department of Psychology, Wesleyan University, 207 High Street, Middletown, CT 06459, United States
[c] Women's Health Research at Yale, United States
[d] Community Health and Health Behavior, University at Buffalo, SUNY, Buffalo, NY 14214, United States

ARTICLE INFO

Article history:
Received 20 December 2013
Received in revised form 23 June 2014
Accepted 4 July 2014
Available online 14 July 2014

Keywords:
Nicotine
Dependence
Cigarette
Smoking
Trends

ABSTRACT

Background: It is unclear whether declines in cigarette smoking in the U.S. have resulted in a hardened population of "hardcore" smokers. We studied changes in nicotine dependence severity from 2002 to 2012, using data from the National Survey on Drug Use and Health.
Methods: We used generalized non-linear factor analysis to examine whether individual Nicotine Dependence Syndrome Scale (NDSS) items functioned differently over time, and whether average NDSS scores changed in a sample of 130,637 current smokers. We also examined trends for individual NDSS sub-scales and whether trends were moderated by tobacco consumption and socio-demographic factors.
Results: Consumption levels and dependence severity both declined over the study period. This decline was driven by priority (e.g., avoiding smoke-free locations) and tolerance dimensions of dependence, while drive (e.g., craving and smoking to relieve negative affect) and continuity (e.g., stability) of smoking did not change. Declines for tolerance were greatest among those without serious psychological distress and among middle-aged smokers. Drive and continuity increased among women and low income smokers.
Conclusions: We did not find evidence of hardening at the population level for smokers in the U.S., 2002–2012. However, there is evidence of hardening when considering drive and continuity-related nicotine dependence among women and low-income smokers, suggesting these sub-groups are experiencing greater severity of craving, smoking to relieve negative affect, and regularity of smoking despite reduced consumption.

1. Introduction

The prevalence of cigarette smoking continues to decline in the U.S. (Substance Abuse and Mental Health Services Administration (SAMHSA), 2012). Reductions in smoking are likely the result of a combination of efforts, including public health, improved treatment, and changes in attitudes toward smoking (Cummings et al., 2009). There is concern that tobacco control efforts and concomitant reductions in smoking have resulted in a "hardened" population of remaining smokers, who may have more difficulty quitting (National Cancer Institute, 2003; Warner and Burns, 2003).

Previous investigations of trends in nicotine dependence severity have primarily used cigarettes per day, or other measures of consumption, as a marker for dependence (Al-Delaimy et al., 2007; Goodwin et al., 2009; Hyland and Cummings, 2003). The majority of these studies have found either no change or declines in cigarettes per day over time, suggesting dependence severity is not increasing at the population level. However, changes in cigarettes per day and other consumption-based measures of dependence severity may be influenced by factors such as taxation and stigmatization, and thus may not adequately document whether or not dependence severity has increased over time (Hughes, 2003). O'Connor et al. (2006) improved on these previous studies by examining both cigarette consumption and serum cotinine levels from 1988 to

☆ Supplementary material can be found by accessing the online version of this paper. Please see Appendix A for more information.

* Corresponding author at: Department of Psychiatry, Yale University School of Medicine, 2 Church Street South, Suite 109, New Haven, CT 06519, United States. Tel.: +1 203 737 3554; fax: +1 203 737 4243.
E-mail address: philip.h.smith@yale.edu (P.H. Smith).

http://dx.doi.org/10.1016/j.drugalcdep.2014.07.003
0376-8716/

2002, finding declines in both measures. Contrarily, a more recent investigation found serum cotinine levels had not changed from 1988 to 2012 (Jarvis et al., in press). Although studies of serum cotinine provide more objective measures of nicotine exposure, the studies do not capture other dimensions of dependence severity, such as tolerance, withdrawal and craving. Measures that capture both consumption and non-consumption dimensions of nicotine dependence severity may be better suited for accurately assessing change over time (Hughes, 2011).

Two population-based, retrospective birth-cohort studies used DSM measures of nicotine dependence to examine whether dependence increased with decreasing age of cohorts (Breslau et al., 2001 – DSM-III; Goodwin et al., 2009 – DSM-IV), with both finding evidence that smokers were becoming more dependent. These retrospective birth cohort studies have important limitations. For example, previous research has demonstrated differential recall bias between younger and older birth cohorts (Johnson and Schultz, 2005). Further, Hughes (2003) found that smokers in younger cohorts were more willing to label their nicotine addiction as dependence than older cohorts. The results may also be biased by differential mortality, whereby heavier smokers in older cohorts are more likely to have passed away than lighter smokers.

The purpose of the current investigation was to assess whether dependence levels changed among smokers in the general U.S. population from 2002 to 2012. This time period is particularly relevant, given the number of improvements in tobacco control efforts that occurred in the early-mid 2000s (e.g., smoke-free policies, increased tobacco taxation and price of cigarettes, FDA approval of varenicline). The study improved upon existing research on this topic in several important ways. First, we used serial cross-sectional data from the National Survey on Drug Use and Health to examine changes over time. Second, we used the Nicotine Dependence Syndrome Scale (NDSS; Shiffman et al., 2004), a measure that captures both consumption and non-consumption dimensions of nicotine dependence. In addition to examining trends based on this comprehensive assessment of dependence severity, we were also able to conduct analyses of trends for specific dimensions of dependence, using item-level and subscale analyses. We first conducted Item Response Theory and Differential Item Functioning analyses to examine changes in the performance of individual NDSS items over time, and to generate overall dependence severity factor scores. We then examined trends for the following NDSS sub-scales: drive (e.g., craving and smoking to reduce negative affect), priority (e.g., avoid places where smoking is restricted), tolerance, and continuity (e.g., smoking regularly throughout the day). We tested moderation of trends for overall dependence severity and NDSS sub-scales by factors related to nicotine dependence severity: daily cigarette consumption, other tobacco product use, sex, age, race/ethnicity, income, and serious psychological distress.

2. Methods

We analyzed data from the National Survey on Drug Use and Health (NSDUH; formerly the National Household Survey on Drug Abuse), an annual nationally representative survey of the U.S. non-institutionalized population, ages 12 and older. This time period (2002–2012) was the longest period available with a consistent measure of nicotine dependence. Computer-assisted, face-to-face interviews were conducted each year by professionals from the Research Triangle Institute. Full details regarding the sampling procedures can be found at the SAMHSA Substance website (SAMHSA, 2013).

Important changes were made to the NSDUH sampling design during the 2002–2012 period. Subsequent to 2005, census tracts were used for the first stage of sampling rather than pre-defined geographical areas. First-stage sampling units had 50% overlap for each consecutive year from 2002 to 2004, and then again from 2004 to 2012 in order to improve consistency between samples (without overlapping respondents; SAMHSA, 2013). Our study was limited to current smokers (100+ cigarettes in their lifetime and at least once during the past 30 days). The sample sizes for each survey year were: 2002, $n = 12{,}757$; 2003, $n = 12{,}967$; 2004, $n = 12{,}599$; 2005, $n = 12{,}434$; 2006, $n = 11{,}978$; 2007, $n = 11{,}934$; 2008, $n = 11{,}617$; 2009, $n = 11{,}470$; 2010, $n = 11{,}343$; 2011, $n = 11{,}169$; 2012, $n = 10{,}412$. The total sample size was $n = 130{,}637$ smokers. The age distribution for smokers in this final combined sample was as follows: 12–17 years – 8.69%; 18–25 – 48.70%; 26–34 – 15.09%; 35–49 – 19.16%; 50–64 – 6.59%; 65 or older – 1.77%. Fifty-two percent were men; 72% were white/Caucasian, 9.5% were Black/African American, and 10.5% were Hispanic; and the median income category was $20,000–49,000.

2.1. Summary of analyses

2.1.1. Trends for general nicotine dependence severity. We used the Nicotine Dependence Syndrome Scale (Shiffman et al., 2004) as our primary measure of nicotine dependence. This measure has demonstrated strong psychometric properties as a multi-dimensional assessment of nicotine dependence (e.g., associations with dependence-relevant measures, prediction of withdrawal/urges to smoke/cessation, high internal reliability, and adequate test–retest reliability; Shiffman et al., 2004). We considered two options for analyzing trends for overall dependence severity. The first and simplest option was to generate summary NDSS scores for each smoker, and compare mean scores across years in the study. This approach had important limitations, such as the skewed nature of the variable's distribution, and the inability to examine trends for individual symptoms over time [i.e., differential item functioning (DIF; Liu et al., 2013)].

In order to resolve these issues, we adapted integrated data analysis (IDA) methodology to our study aims, and used moderated nonlinear factor modeling (MNLFA) as our main analytic tool (Bauer and Hussong, 2009; Rose et al., 2013). This approach allowed us to do four things: (1) examine differential item functioning for individual items in 2003–2012 relative to 2002, (2) use this information to generate a psychometrically equivalent measure of nicotine dependence across 2002–2012, (3) generate nicotine dependence severity scores for each participant based on this psychometrically equivalent measure, and (4) examine whether both mean and variance for nicotine dependence severity changed from 2002 to 2012.

IDA is a general framework of methods for combining data from varying samples, by creating psychometrically equivalent measures across studies. We achieved this goal by utilizing MNLFA, which is rooted in generalized linear modeling and item response theory (IRT; Bauer and Hussong, 2009). IRT is based on the assumption that items from a measure (in this case, NDSS) are representative of a range of ability (in this case nicotine dependence severity) for a single underlying, normally distributed latent factor (nicotine dependence). Our base model was a 2-PL IRT model (Embretson and Reise, 2000). In this model, each item in the measure has an item location parameter (the level of nicotine dependence severity represented by that item) and a discrimination parameter (each item's ability to differentiate between those scoring higher and lower on nicotine dependence severity). These parameters can then be used with any given individual's item responses to generate a factor score (each smoker's nicotine dependence severity) for that individual.

MNLFA is able to extend on this base 2-PL IRT model in two important ways. First, the model can include estimates for the mean and variance of the factor scores. Second, one can include interaction terms for model parameters, allowing for a test of effect moderation by other key variables. For example, in the current investigation, this approach allowed us to examine whether item location and item discrimination were moderated by study year (i.e., testing item DIF), and whether mean factor score and variance were moderated by study year (i.e., testing whether overall nicotine dependence or variance in nicotine dependence varied by year, after accounting for DIF).

All analyses for the current investigation were conducted using MPlus (to generate initial parameter estimates), and SAS PROC NLMIXED (to conduct MNLFA modeling and generate nicotine dependence scores). NDSS responses for each item ranged from 1 to 5 ("not at all true" to "extremely true"). First, we dichotomized the items to fit the 2-PL IRT model. We re-coded each NDSS symptom to 0 or 1, based on whether the respondent reported the symptom was at least "somewhat true" of them. We used "somewhat true" as a cut-off because this translated to a "yes vs. no" response for whether the respondent had experienced the symptom. This approach is consistent with other non-consumption based measures of nicotine dependence (e.g., the DSM). We then conducted factor analyses on the NDSS symptoms in order to select items that best represented a single latent nicotine dependence factor for further analyses. We also wanted to limit our analyses to the most parsimonious number of symptoms possible, while maintaining an adequate representation of nicotine dependence. Our final selection of NDSS items is presented in Table 1.

When calculating MNLFA models, we used adaptive Gaussi-Hermite quadrature, specifying 15 quadrature points and a maximum of 1000 iterations, and a gradient cut-off of 0.01. We considered DIF to be evident if both of two criterion were satisfied: (1) the DIF coefficient (i.e., the interaction between item location/discrimination and study year) for an item was statistically significant between study years ($p < 0.05$), *and* (2) the parameter estimate was greater than 0.2. We used the second criterion because with such a large sample size, even non-meaningful DIF was found to be highly statistically significant (even after accounting for multiple testing). We selected the cut-off of 0.2 because the parameter estimates have a scale of standardized units, and effect sizes <0.2 are generally accepted to be small (Kirk, 1996). After testing DIF for each item, we generated a nicotine dependence score for each smoker, controlling for statistically significant DIF (i.e., each participant's nicotine dependence score was based on an underlying latent construct that was equivalent across study years).