Drug and Alcohol Dependence 185 (2018) 33–39

Contents lists available at ScienceDirect

Drug and Alcohol Dependence

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

Full length article

E-cigarette use and quantity of cigarette smoking among adolescent cigarette smokers: A finite mixture model analysis

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ARTICLE INFO

Keywords:
Tobacco
Electronic cigarettes
Finite mixture model
Combustible cigarettes
Smoking intensity
Adolescents

ABSTRACT

Background: E-cigarette use is popular among adolescents and youth, but its long-term public health implications remain largely unknown. Much of the literature has focused on understanding the relationship between e-cigarette use and youth cigarette initiation. However, very little is known about e-cigarette use and cigarette quantity among those who continue to smoke cigarettes. The objective of the present study was to examine the association between current e-cigarette use and quantity of cigarette smoking.

Methods: Cross-sectional data on current smokers were drawn from the 2014–2015 Canadian Student Tobacco, Alcohol and Drugs Survey among high school students (n = 1411). A finite mixture model (FMM) was employed to account for unobserved heterogeneity due to clusters of finite sub-populations.

Results: Current e-cigarette users reported smoking more conventional cigarettes in the past week compared to non-e-cigarette users (t [1409] = 4.7998; $p < 0.001$ in unadjusted analysis). Results from a finite mixture regression showed that current e-cigarette use was significantly associated with the number of cigarettes smoked in the past week, but only among light smokers (IRR = 1.40; CI = 1.05–1.85). However, additional analyses found that the association between e-cigarette use and quantity of cigarette smoked varied by individual smoking pattern. An FMM with a group or class modelling using individual smoking pattern showed a weaker association between e-cigarette use and quantity of cigarette smoking.

Conclusion: Findings of this study suggest that the significant association between e-cigarette use and quantity of cigarette smoking may be driven by patterns of use among experimental or beginner smokers.

1. Introduction

Conventional cigarette use by adolescents has declined in many jurisdictions in the past several decades (Reid et al., 2015; Collishaw, 2009; U.S. Department of Health and Human Services, 2012). A diverse set of alternative products (hereafter, e-cigarettes) has become popular among adolescents and youth (U.S. Department of Health and Human Services, 2016; Grana et al., 2014; Singh et al., 2016; Montreuil et al., 2017; Goniewicz et al., 2014a; Bauld et al., 2015). With e-cigarettes, users inhale an aerosol, which often contains nicotine, along with propylene glycol and/or glycerin, flavorings, and other chemicals.

Although the long-term health effects of e-cigarettes are unknown, they may contain fewer toxic chemicals than conventional cigarettes (Goniewicz et al., 2014b; Hajek et al., 2014; Farsalinos and Polosa, 2014). As a result, some researchers and government bodies have predicted that e-cigarettes could disrupt the use of combustible tobacco products (Flahault and Etter, 2014; Cahn and Siegel, 2011; Hajek et al., 2014; Farsalinos and Polosa, 2014; McNeill et al., 2015). While the long-term effects remain unclear, many believe that e-cigarettes offer health benefits if they are substituted for combustible tobacco products. However, studies examining whether e-cigarette use promotes smoking cessation have produced mixed findings to date (Bullen et al., 2013; Polosa et al., 2011; Al-Delaimy et al., 2015; Sutfin et al., 2015; Pearson et al., 2014). A recent meta-analysis showed that the odds of quitting cigarettes were 28% lower among those who used e-cigarettes relative to conventional cigarette users (Kalkhoran and Glantz, 2016).

There also are concerns that the decades of progress made to prevent and reduce the uptake of tobacco use – especially among youth – may be compromised by the increasing popularity of e-cigarettes (Rigotti, 2015; American Lung Association, 2015; Brandon et al., 2015; Canadian Medical Association, 2014; Stanwick, 2015). While many e-cigarette users also smoke cigarettes, young non-smokers may experiment first with e-cigarettes (Czoli et al., 2014; U.S. Department of Health and Human Services, 2016). An accumulating body of evidence suggests that e-cigarettes may be a starter product to cigarette initiation (Miech et al., 2017; Barrington-Trimis et al., 2016; Dutra and Glantz,

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https://doi.org/10.1016/j.drugalcdep.2017.12.003
Received 4 September 2017; Received in revised form 20 December 2017; Accepted 20 December 2017
Available online 31 January 2018
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2014; Leventhal et al., 2015; Sutfin et al., 2015; Primack et al., 2015; Wills et al., 2016a,b).

Similar to previous research on the association of e-cigarette use and smoking cessation, much of the literature has focused on understanding the relationship between e-cigarette use and youth cigarette initiation. However, very little is known about e-cigarette use and quantity of cigarette smoking among those who continue to smoke cigarettes (Doran et al., 2017; Wills and Sargent, 2017; Goniewicz et al., 2016). While there is no safe level of tobacco use, understanding whether e-cigarette use is associated with lower frequency or intensity of smoking is crucial, given that a gradual reduction in cigarette use is a potential pathway to permanent quitting, at least for some (Wills and Sargent, 2017; Hughes and Carpenter, 2006). A study of Polish cigarette smokers aged 16–18 years found e-cigarette users were more likely to smoke cigarettes than those who did not use e-cigarettes (Goniewicz et al., 2016). Using longitudinal data on young adult (aged 18–24) non-daily cigarette smokers in California, Doran and colleagues found e-cigarette use was significantly associated with higher quantity and frequency of cigarette smoking (Doran et al., 2017). While the study by Doran et al. (2017) is an important addition to the extant literature, the current study used a different approach, and provides further insights on the pattern of association between e-cigarette use and the intensity of adolescents' cigarette smoking.

Specifically, the present study contributes to the extremely limited evidence base on e-cigarette use and quantity of cigarette smoking. We employed a more flexible estimation approach, a finite mixture model (FMM), as our method of analysis. Standard count models, such as Poisson regression, yield an average population estimate, which constrains the effects of covariates to be equal for all individuals. This may be less informative if the average population estimate masks considerable variation in smoker types. For example, unobserved heterogeneity may not be fully captured by observed characteristics or proxy variables due to inherent differences between smokers. Unlike average estimates from a single component distribution, an FMM can account for unobserved heterogeneity that clusters around a finite set of subpopulations (Azagba et al., 2013; Azagba and Sharaf, 2011; Cameron and Trivedi, 2013; McLachlan and Peel, 2000; Deb and Trivedi, 1997; Tomczyk et al., 2015; Tomczyk et al., 2016). Due to its flexibility, FMM has wide use across various fields, including genetics, biometrics, medicine, psychiatry, social sciences, and marketing (McLachlan and Peel, 2000; Schlattmann, 2009). We used FMM to analyze data from a large dataset of Canadian adolescents and youth in order to elucidate relationships between e-cigarette and cigarette smoking.

2. Methods

2.1. Data

Data were obtained from the 2014–2015 Canadian Student Tobacco, Alcohol and Drugs Survey (CSTADS). Briefly, CSTADS (formally known as the Youth Smoking Survey) is a nationally representative, school-based survey of Canadian students. It collects information about adolescent and youth tobacco, alcohol and drug use, and corresponding socio-demographic characteristics (Elton-Marshall et al., 2011). The target population for CSTADS consists of young, Canadian residents attending private and public schools, enrolled in grades 6 through 12. The survey excluded those living on First Nations reserves, Canada's three northern Territories (Yukon, Nunavut, and Northwest Territories), and those attending special schools or schools on military bases. CSTADS uses a stratified single-stage cluster design with strata based on health region, smoking rate, and type of school. In each province, two or three health region smoking rate strata and two school-level strata were defined. Random selection of schools within each stratum ensured a generalizable sample of schools for each province. Research ethics boards at multiple levels approved the study: Health Canada, University of Waterloo and institutions and school boards in each participating province. Consistent with school board requirements, parents provided permission for their child to participate in the study via active parent permission or active information-passive permission protocols. Only students with parental permission were invited to participate in the study on the day of survey implementation. Students were not remunerated and could opt out at any time. A total of 42,094 students in grades 6–12 completed the survey, corresponding to 66% of the eligible student population in participating classes.

2.2. Measures

The outcome variable, quantity of cigarette smoking, defined as the total number of cigarettes smoked the week prior to the survey, was derived based on responses from those who ever smoked a whole cigarette in their lifetime. We restricted the sample of the present study to high school student (grades 9–12) who were current cigarette smokers (smoked cigarettes in the 30 days prior to the survey). We excluded those in elementary school due to low smoking rates in this group (Health Canada, 2017). Approximately 11% of grades 10–12 students are cigarette smokers (representing 6.6% as daily and occasional smokers, and 4.6% as experimental smokers; Health Canada, 2017). Consistent with previous studies (Goniewicz et al., 2016; Bunnell et al., 2014; Coleman et al., 2014), we defined current e-cigarette users as those who responded "yes" to whether they had used e-cigarettes in the 30 days prior to the survey; a "no" response was classified as non-current e-cigarette use. The analysis controlled for several variables, including sex, grade level (9–12), exposure to cigarette smoking (using the question, "During the last 30 days, did you ride in a car with someone who was smoking cigarettes?"), level of urbanization (urban, rural), school-level median household income – measured continuously (the first three digits of the postal code of the respondent's school were used to extract school-level median household income from the 2011 Canadian Census data), and region of residence—East (Newfoundland and Labrador, Prince Edward Island, New Brunswick, and Nova Scotia), West (Saskatchewan, Alberta, Manitoba, and British Columbia), Quebec, and Ontario. Among high school students who used cigarettes in the last 30 days (n = 2776), 53% reported quantity of cigarettes consumed (n = 1474), about 95% reported current e-cigarette status (n = 2643) and exposure to secondhand smoke in a car (n = 2636). Our final analytic sample included 1411 smokers. Based on the focus of the study, we excluded those with missing data on quantity of cigarette smoked. Assuming a mass of zeros for those with missing quantity would be problematic, given that we could not differentiate a quitter (former smoker) or actual 'zero' consumption from current smokers. However, we examined if the nature of missing-ness is systematic among key demographics (gender and school-level median household income), and no statistically significant associations were found.

2.3. Statistical analysis

To examine associations between current e-cigarette use and the total number of cigarettes smoked in the past week, a finite mixture negative binomial model was estimated to account for unobserved population heterogeneity. The FMM captures variations in the parameter of interest (in this case, e-cigarette use) over diverse and mutually exclusive subpopulations (Bohning and Seidel, 2003; Cameron and Trivedi, 2013; McLachlan and Peel, 2000). Unlike one-population estimates with a single component distribution, a FMM can account for unobserved heterogeneity that clusters around a finite set of subpopulations (Cameron and Trivedi, 2013; McLachlan and Peel, 2000; Deb and Trivedi, 1997). The FMM posits that a population is composed of two or more distinct unobserved subpopulations or groups with unknown mixing weights or proportions. The mixing weights (also known as a class or component probabilities) are estimated along with the other model parameters of interest (Cameron and Trivedi, 2013; McLachlan and Peel, 2000). A finite mixture yields valid estimates even

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