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An examination of the shift in school-level clustering of US adolescent electronic cigarette use and its multilevel correlates, 2011–2013

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ABSTRACT

The percent of US high school students reporting use of electronic cigarettes (i.e., e-cigarettes) tripled in recent years. Little is known about the temporal shifts in school-level e-cigarette prevalence or the multilevel correlates of teen e-cigarette use. Using multilevel regression techniques and data from the 2011 and 2013 US National Youth Tobacco Surveys, we investigate how the school-level clustering of e-cigarette use has shifted between 2011 and 2013, whether school-level e-cigarette use is associated with individual-level use, and whether this association is explained by perceptions of harm attributed to e-cigarettes. Results indicate that school-level clustering of pastmonth e-cigarette use increased between 2011 and 2013. Multilevel models show that school-level e-cigarette use is positively associated with individual use, with a small proportion of this relationship explained by perceived harm of e-cigarettes. Our findings suggest that schools could have become more differentiated from each other based on their prevalence of e-cigarette use, and that certain types of school environments facilitate e-cigarette use more efficiently than others.

1. Introduction

Many in the medical community have welcomed electronic cigarettes, or "e-cigarettes", as novel devices with potential application in harm reduction for smokers of conventional cigarettes. Giving cause to this enthusiasm, empirical evidence from randomized controlled trials indicates that e-cigarettes generally perform at least as well as other nicotine-replacement therapies (e.g., gum, patch) in curbing adult cigarette cravings (Bullen et al., 2010; Caponnetto et al., 2013; Polosa et al., 2011). However, longitudinal studies based on observational data find no association between e-cigarette use and tobacco cessation (Adkison et al., 2013; Grana et al., 2014), and some find that daily nicotine intake is *higher* among e-cigarette users versus combustible cigarette smokers (Borderud et al., 2014).

Notwithstanding applications in tobacco cessation and nicotine replacement, some have cautioned that the risks of e-cigarettes remain unclear (Cobb et al., 2010; Riker et al., 2012), and that thoughtfully-designed regulations are warranted. One concern is that e-cigarettes may facilitate adolescent nicotine addictions (Dutra and Glantz, 2014). Recent estimates from the National Youth Tobacco Surveys warrant this concern: between 2011 and 2012 the prevalence of adolescent e-cigarette use among high school students doubled, from 4.7% to 10% (Centers for Disease Control and Prevention, 2013)—a rate that is comparable to those found in some European contexts with historically high adolescent smoking rates (Durmowicz, 2014). Evidence also suggests that e-cigarettes may be overtaking conventional cigarettes in popularity, with 16% of 10th graders in the 2014 Monitoring the Future Study reporting past-month e-cigarette use versus 7% reporting past-month conventional cigarette use (Johnston et al., 2015). In response to these trends, numerous studies have examined the individual-level correlates of teen e-cigarette use. However, no research to our knowledge has investigated the school-level correlates of e-cigarette use or how the importance of schools as contexts for the production and reproduction of adolescent e-cigarette use has shifted over time.

Guided by theory and past findings linking school contexts to youth tobacco use (Cole and Leatherdale, 2014; Murray et al., 2002), we expect that the increase in adolescent e-cigarette use has occurred alongside uneven increases in the rate of e-cigarette use across schools. Not all schools are likely to have contributed equally to the population-wide increase in teen e-cigarette use. Instead, we argue that certain schools will have experienced pronounced increases in adolescent e-cigarette use between 2011 and 2013, while others will have experienced subtle changes. Because only cross-sectional data are currently available we cannot

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test this hypothesis directly by tracking the same schools over time, but our argument would be consistent with results from year-specific multilevel models showing that, between 2011 and 2013, schools became *more* differentiated by their rate of e-cigarette use. In statistical terms, between 2011 and 2013 the year-specific school-level clustering coefficient would have increased under this scenario. Such a finding would indicate an increasingly important role of school environments for adolescent e-cigarette use, which would be useful information in terms of nicotine prevention activities.

This expectation is also consistent with the conceptual framework proposed by Frohlich et al. (2001, 2002), who view health behaviors as "generated practices" that are created by and recreate the contexts in which human lives are embedded. Over time, as more students within particular schools adopt e-cigarette use, contextual traits (e.g., rate of e-cigarette use; prescriptive social norms) are reinforced as are the collective lifestyles that distinguish certain contexts from others. Again, this cycle would be consistent with an increase in the magnitude of differentiation between schools based on their rate of e-cigarette use, approximated by year-specific school-level clustering coefficients.

Based on these expectations, we use repeated cross-sectional data from the 2011 and 2013 waves of the National Youth Tobacco Survey (NYTS) to answer three questions: (1) Have schools become more or less differentiated by adolescent e-cigarette use between 2011 and 2013? (2) Is school-level e-cigarette use associated with individual use net of personal traits? (3) Do perceptions of risk associated with e-cigarette use attenuate the association between school-level e-cigarette use and one's own use? We are able to answer these questions through multilevel regression techniques, evaluating the changing school-level clustering from 2011 to 2013, and observing the marginal effect of school-level e-cigarette use on individual-level use with and without adjustments for perceptions of the harm caused by e-cigarettes.

2. Background

2.1. E-cigarettes and the increase in adolescent use

E-cigarettes have enjoyed endorsements from many health experts as safer alternatives to combustible cigarettes, but this may be premature. It remains unclear how much safer e-cigarettes truly are in comparison to conventional cigarettes. E-cigarette nicotine cartridges host a number of toxic elements including propylene glycol and diethylene glycol, and secondhand "vapor" may contain similarly toxic agents (Schober et al., 2014). A recent study shows that the amount of carcinogenic formaldehyde present in e-cigarette vapor is higher than that found in tobacco cigarettes under certain conditions (Jensen et al., 2015). Further, the evidence linking e-cigarette use to reductions in tobacco use is equivocal. One recent study found lower smoking desires following overnight abstinence among adults randomized to e-cigarettes versus nicotine inhalers or placebo (Bullen et al., 2010). Evidence from several longitudinal studies suggests that this may translate into longer-term reductions in conventional cigarette use (Biener and Hargraves, 2015; Caponnetto et al., 2013; Polosa et al., 2011). Conversely, some evidence suggests a null association between e-cigarette use and smoking cessation (Grana et al., 2014), or in some cases a *positive* association between e-cigarette use and smoking at follow-up (Borderud et al., 2014).

Some public health advocates argue that thoughtful regulation and restraint among the medical community is needed until the benefits and risks of e-cigarettes are clear (Riker et al., 2012). Among these risks is the potential for e-cigarettes to undermine recent reductions in adolescent nicotine use. E-cigarettes could roll back this progress for several reasons. First, regulatory ambiguities make e-cigarettes more available to minors than tobacco cigarettes. As of early 2015, one-fifth of US states permit e-cigarette sales to minors and internet sales are almost entirely unregulated, even in states that require age verification for e-cigarette purchases (Williams et al., 2015).

Second, an expanding line of e-cigarette accessories may be both appealing and purposefully targeted to adolescent consumers. Nicotine pouches come in palatable, candy-like flavors including pina colada, bubble gum, and cookies and cream. In 2009, the use of such flavors in conventional cigarettes was banned by Congress to discourage smoking initiation among minors (U.S. House of Representatives, 2009), but e-cigarettes are exempt from this policy. Also, the technological novelty of personalized e-cigarettes and "e-pipes" may be utilized by adolescents to communicate status or socioeconomic position (Chapman, 2014). Ironically, the most ornamental and costly e-pipe models heat their nicotine cartridges at higher temperatures, which may elevate the carcinogenic properties of vaping (Jensen et al., 2015).

Third, policies regulating the advertising of other nicotine products to minors have not been modified to include e-cigarettes. Thus, it remains legal to advertise e-cigarettes on the internet, television, and radio. Indeed, scholars find that teen-directed e-cigarette advertisements have increased in recent years (Duke et al., 2014). Analyses of e-cigarette advertisements also reveal disturbing findings about their content. For instance, Grana and Ling (2014) find that well over half of online e-cigarette retailers make unsubstantiated claims about the health virtues of e-cigarettes, and a considerable percentage link e-cigarette use to modernity (73%), heightened social status (44%), and celebrity-like behavior (22%). Such messages parallel those found in late-20th century tobacco advertisements that portrayed smoking as glamorous, benign, and normative—messages that contradict both empirical evidence and the controversial use of stigma in anti-smoking campaigns (Bayer, 2008).

Concerns regarding weak regulation, merchandise with teen appeal, and teen-directed marketing have emerged against the backdrop of recent trends suggesting that e-cigarette use is becoming more normative among US teens. Attention to adolescent e-cigarette use was elevated by a 2013 CDC report indicating that the percent of adolescents who had ever used an e-cigarette doubled between 2011 and 2012—from 4.7% to 10% among high schoolers and from 3.3% to 6.8% among all students in grades 6–12 (Centers for Disease Control and Prevention, 2013). A subsequent report based on data from the Monitoring the Future study showed that in 2014 the prevalence of past-month e-cigarette use among high schoolers (17.1%) had outpaced tobacco cigarette use (13.6%; Johnston et al. (2015)). This trend is alarming in part because it runs counter to the general pattern of declining adolescent nicotine use between 1997 and 2013 (Johnston et al., 2014), and could signal the emergence of a gateway to teen tobacco use. Indeed, recent studies show that lifetime use of e-cigarettes is associated with greater openness to try tobacco in the future (Bunnell et al., 2015; Coleman et al., 2015; Wills et al., 2015) and increased likelihood of cigarette, cigar, and hookah use at six- and 12-month follow-up interviews among a cohort of tobacco abstinent US adolescents (Leventhal et al., 2015).

Multiple studies have since identified certain individual-level traits common among adolescent e-cigarette users in the US, including male gender, non-Hispanic white race, older age, and being a smoker of conventional cigarettes or being friends with a smoker (Anand et al., 2015; Dutra and Glantz, 2014; Lippert, 2014). However, evidence from other studies yield some contrary findings. For instance, in a study of Welsh adolescents Moore and colleagues (Moore et al., 2015) found no differences in the odds of