



## Emergence of electronic cigarette use in US adolescents and the link to traditional cigarette use



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### HIGHLIGHTS

- An innovative method is used to examine age trends in adolescent e-cigarette use from a large, contemporary data set.
- Rates of e-cigarette use increase faster than traditional cigarette use from ages 13–16.
- Risk for e-cigarette use was higher for male and Hispanic adolescents at certain ages.
- E-cigarette and traditional cigarette use were strongly associated throughout adolescence, particularly prior to age 15.

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### ABSTRACT

**Background:** Electronic cigarettes (e-cigarettes) are increasingly used by US adolescents and may be a gateway to traditional cigarette use. We examine rates of both products by age and examine differences in age-varying rates by sex and race/ethnicity.

**Methods:** Data are from the 2014 National Youth Tobacco Survey, a national sample of US middle and high school students ( $n = 22,007$ ); students ages 11–19 were included. Past 30-day e-cigarette and traditional cigarette use were examined as a function of age; sex and race/ethnicity were included as moderators. The age-varying association between e-cigarette and traditional cigarette use was also examined.

**Results:** Rates of e-cigarette use increase faster than traditional cigarette use from ages 13–16. Compared to females, males had higher rates of e-cigarette use from ages 14–17.5 and traditional cigarette use from ages 15–18. Between ages 12–14, more Hispanic adolescents used e-cigarettes compared to White or Black adolescents; after age 14 Hispanics and Whites reported similar rates, peaking at twice the rate for Blacks. Hispanic adolescents report greater traditional cigarette use versus Whites between ages 12–13, but lower rates between ages 15–18. E-cigarette use was strongly associated with traditional cigarette use, particularly during early adolescence [ $OR > 40$  before age 12].

**Conclusions:** Young Hispanic adolescents are at elevated risk for use of e-cigarettes and traditional cigarettes during early adolescence. During early adolescence, youth using e-cigarettes are more likely to smoke traditional cigarettes compared to youth not using e-cigarettes. The study of age-varying effects holds promise for advancing understanding of disparities in health risk behaviors.

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Electronic cigarettes, or e-cigarettes, were developed as a “reduced harm product,” (Cobb, Byron, Abrams, & Shields, 2010) and have been touted by some as a “safe alternative” to traditional cigarette smoking. Although recent work suggests that e-cigarettes may be less harmful than traditional cigarettes (Foulds, 2015; McNeill et al., 2015; Nutt,

Phillips, Balfour, et al., 2014), concerns remain regarding their potential long-term health effects, as well as the potential for influencing use of additional tobacco products (Pepper & Brewer, 2013). There is additional concern regarding the rise in adolescent e-cigarette use, which surpassed adult use in 2012 (Chapman & Wu, 2014). Research suggests that adolescent e-cigarette use increased by approximately 69% from 2011 to 2013 (Bunnell, Agaku, Arrazola, et al., 2014), and nearly tripled from 2013 to 2014 (Arrazola, Singh, Corey, et al., 2015). These increases have pushed the prevalence of e-cigarette use above that of traditional cigarette use among US adolescents, with data from the 2014 National Youth Tobacco Survey (NYTS) showing that 13.4% of high-school

*Abbreviations:* NYTS, National Youth Tobacco Survey; TVEM, time-varying effect modeling; OR, odds ratio.

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adolescents reported using e-cigarettes in the past 30 days, compared to 9.2% who reported past 30-day use of traditional cigarettes (Arrazola et al., 2015). Given that e-cigarettes may be easily accessible to adolescents and the introduction of flavoring may make them particularly appealing at this age, it is critical to understand the context of e-cigarette use among adolescents.

Emerging evidence suggests a strong likelihood of individuals using both e-cigarettes and traditional cigarettes (Camenga, Delmerico, Kong, et al., 2014; Dutra & Glantz, 2014; Porter, Duke, Hennon, et al., 2015). However, little is known about how the most recent prevalence estimates of e-cigarette use vary as a function of adolescent age, and even less is known about how the association between e-cigarette use and traditional cigarette smoking varies throughout adolescence. This is important to understand, given consistent evidence that the age of experimentation with tobacco products is associated with future nicotine dependence. Particularly, tobacco use in early adolescence (i.e., prior to age 15) strongly predicts addiction later in life (Behrendt, Wittchen, Höfler, Lieb, & Beesdo, 2009; Breslau, Fenn, & Peterson, 1993; Lanza & Vasilenko, 2015).

Although some adolescent e-cigarette users have never smoked traditional cigarettes (Camenga et al., 2014; Corey, Wang, Johnson, et al., 2013), emerging evidence shows that adolescents who exclusively use e-cigarettes have greater intent to use traditional cigarettes in the future (Bunnell et al., 2014; Park, Seo, & Lin, 2016). These findings raise concern that adolescent e-cigarette use could promote future cigarette smoking due to the development of nicotine addiction, and/or increased accessibility to multiple tobacco products via commercial and social sources (Grana, 2013; Schneider & Diehl, 2016). Individual predispositions (e.g., risk-taking and sensation seeking behavior) and social determinants (e.g., socioeconomic status) may also promote the use of both products independently, regardless of which is used first (Schneider & Diehl, 2016).

Disparities across sex and race/ethnicity subgroups in these behaviors are important to consider, given evidence for sex and racial/ethnic differences in smoking during adolescence and into adulthood. Male adolescents display higher rates of traditional and e-cigarette smoking compared to females, and White adolescents display higher rates of traditional cigarette smoking compared to Hispanic and Black adolescents (Arrazola et al., 2015; Chen & Jacobson, 2012; Littlefield, Gottlieb, Cohen, & Trotter, 2015). However, Hispanic and White adolescents have demonstrated similar rates of e-cigarettes use, both groups using at a higher rate than Black adolescents (Arrazola et al., 2015).

The current study is exploratory in nature, focusing on contemporary age trends in emergent e-cigarette use, recent traditional cigarette use, and the link between the two behaviors among US adolescents aged 11–19. Time-varying effect modeling (TVEM (Li et al.)) is used to document detailed age trends in the prevalence of (1) recent use of traditional cigarettes, (2) recent use of e-cigarettes, and (3) recent use of both products, as well as how these complex age trends vary across sex and racial/ethnic population subgroups. This innovative approach enables the investigation of changing associations across age using cross-sectional data, thus providing important age-relevant nuances that are likely obscured when using more traditional approaches. Prior applications of TVEM in nicotine research include estimation of the time-varying association between mood and craving (Lanza, Vasilenko, Liu, Li, & Piper, 2013), craving and cessation fatigue (Liu, Li, Lanza, Vasilenko, & Piper, 2013), and mood and smoking lapse (Vasilenko et al., 2014), across time since quitting in a smoking cessation trial, and the nuanced association between age of onset of regular cigarette use and subsequent use in adulthood (Lanza & Vasilenko, 2015).

## 1. Methods

### 1.1. Sample

Data were drawn from the most recent wave of data (2014) from the National Youth Tobacco Survey (NYTS). NYTS is a nationally

representative, public use dataset which includes information on  $N = 22,007$  middle and high school students' "tobacco-related knowledge, attitudes, and behaviors". (Office on Smoking and Health, 2015) Cross-sectional data were collected using a stratified, three-stage cluster sample design; Hispanic and non-Hispanic Black students were oversampled to enable more precise prevalence estimates for minority populations. Students from 207 schools completed the survey, for an overall participation rate of 73.3% (participation rates were 91.4% and 80.2% for students and schools respectively). The analytic sample contained 21,798 adolescents between ages 11–19 (49% female; 48% non-Hispanic White, 17% non-Hispanic Black, 29% Hispanic); 157 respondents were excluded because their age was reported as younger than 11, and 52 had a missing value for age. The institutional review board at The Pennsylvania State University approved this study by exemption.

### 1.2. Measures

Age was reported to the nearest year, and ranged from 9 years old to 19 years old (or older), with a mean age of approximately 14.5 years. Due to the small proportion of participants younger than 11 (0.7%), only participants aged 11 and older were included in the analysis sample. Sex was measured by self-report; for this analytic sample, 50.7% reported being male and 48.4% female. Race/ethnicity was assessed by a series of self-report questionnaire items, and individuals were assigned to a single category including Non-Hispanic White (45.0%), Non-Hispanic Black (15.6%), or of Hispanic origin (27.6%). Individuals in other race/ethnicity categories (6.3%) were not included in moderation analyses using this variable due to limited statistical power. Recent traditional cigarette use and recent e-cigarette use were assessed via the questions "During the past 30 days, on how many days did you [smoke cigarettes/use e-cigarettes]?" Recent use was coded 0 if no use was reported in the past 30 days and 1 if use was reported.

### 1.3. Analytic approach

Time-varying effect modeling (TVEM) was used to estimate the prevalence rate of traditional cigarette use and e-cigarette use as flexible functions of age, and the age-varying association between e-cigarette and traditional cigarette use. Models were run using logistic TVEM, a semi-parametric model that estimates regression coefficients (e.g., rates and associations between predictors and an outcome) as non-parametric functions of continuous age (Vasilenko et al., 2014). First, intercept-only models estimating the rate of each behavior as a function of age were run for the full analysis sample. Second, models including sex and race/ethnicity as covariates were run to test for subgroup differences in the complex age trends; centering was used to obtain group-specific intercept functions. Next, recent e-cigarette use was included as a predictor of recent traditional cigarette use to estimate the age-varying association between the behaviors. We then added sex and race/ethnicity interactions with recent e-cigarette use to examine possible subgroup differences in this age-varying association. All models were run in SAS 9.4 using the TVEM macro (Li et al.; TVEM SAS Macro Suite (Version 3.1.0) [Software]).

## 2. Results

Among US adolescents ages 11–19, past-30 day traditional cigarette use was reported by 6.4% and past-30 day e-cigarette use was reported by 9.2%. Overall, males were significantly more likely to engage in both behaviors when compared with females (7.5% of males and 5.3% of females reported traditional cigarette use; 10.5% of males and 7.8% of females reported e-cigarette use). The prevalence of both behaviors also varied significantly by race/ethnicity. Traditional cigarette use was most common among White adolescents (7.7%), followed by Hispanic (6.1%) and Black (4.1%) adolescents. E-cigarette use, however, was

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