January 2016

E-Cigarette Use Among Urban Adolescents: A Longitudinal Study Of Prevalence And Predictors Of Use

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E-Cigarette Use among Urban Adolescents:
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by

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Submitted in partial fulfillment of the requirements for the degree of
Master of Public Health

May 2016

Acknowledgements

Abstract

Purpose: In a study of middle school students, the objectives were to (1) document prevalence of early e-cigarette use and characteristics of users, and (2) identify psychosocial and behavioral factors that predict susceptibility and uptake.

Methods: Students in 12 randomly selected public schools in New Haven, Connecticut, completed health and behavior surveys in grades 7 and 8 (N=490). Descriptive statistics were calculated to assess the prevalence of e-cigarette susceptibility (considering e-cigarette use) and e-cigarette uptake among students at grade 7 and grade 8. Multivariate logistic regression analyses were used to assess associations between psychosocial and behavioral characteristics measured at grade 7 and both e-cigarette susceptibility and e-cigarette uptake at grade 8, controlling for school clustering and potential confounders.

Results: In grade 7, only 1.2% (n=6) of students reported using e-cigarettes; there was a seven-fold increase by grade 8, with 8.4% (n=41) of students reporting e-cigarette use. Perceived stress was a predictor of e-cigarette susceptibility (adjusted odds ratio [AOR], 1.21; 95% CI, 1.07-1.36), and school connectedness protected against e-cigarette uptake (AOR, 0.93; 95% CI, 0.87-0.98).

Conclusions: Both individual and organizational psychosocial and behavioral factors in grade 7 were found to be associated with e-cigarette susceptibility and uptake in grade 8. Findings suggest schools may be able to play a role in impacting rates of e-cigarette use among adolescents.

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Background

Electronic Nicotine Delivery Systems (ENDS) refer to devices, such as e-cigarettes, with which users inhale nicotine through an aerosol mist [1]. Since their 2007 introduction in the US, these devices have quickly gained popularity. E-cigarettes contain unpredictable concentrations of nicotine, a notable concern in adolescence. Because the adolescent brain is still developing, they are more vulnerable to adverse effects of nicotine and are at greater risk of nicotine dependence [[1], [2]]. When adolescents use e-cigarettes or other nicotine-containing products, nicotine acts on the developing pre-frontal cortex, affecting cognitive development, functioning, and inhibitory control [2]. Adolescent smoking is associated with deleterious effects on working memory and attention, as well as decreased pre-frontal cortex activation. Animal studies have shown that exposure to nicotine in adolescence causes greater changes in the pre-frontal cortex than during any other period of development [2].

According to estimates from the 2014 National Youth Tobacco Survey, administered to students in grades 6-12 across the United States, e-cigarettes were the most commonly reported nicotine products used among both middle (3.9%) and high school (13.4%) students [3]. Furthermore, from 2011-2014, e-cigarette use increased among middle and high school students, while cigarette use decreased [3]. From 2013 to 2014 in particular, the prevalence of students reporting e-cigarette use in the past 30 days tripled among both middle and high school students [3].

To date, research has been limited on prevalence and correlates of e-cigarette use among adolescents. The majority of literature has focused on associations between e-cigarette use and conventional cigarette use [[4], [5], [6], [7]]. E-cigarettes are typically marketed towards adults as a tool for smoking cessation, and the most common reasons cited by adults for using e-cigarettes include: using in places where smoking is prohibited, reducing smoking, and quitting smoking [8]. However, data from the National Youth Tobacco Survey suggest that among adolescents who smoked conventional cigarettes, neither a desire to quit nor recent quit attempts were significantly associated with e-cigarette use [9]. Even among middle and high school students who had never smoked a conventional cigarette, many had used e-cigarettes (9.3%) [10]. The proportion of students reporting ever using e-cigarettes who had never smoked a conventional cigarette was higher among middle school students (20.3%) compared to high-school students (7.2%) [10].

The social-ecological model has been used to describe early initiation of conventional cigarettes [11]. Synergistic effects between individual, group, organizational, community, and population level factors may influence uptake and provide multiple avenues for intervention [11]. Factors impacting initiation of conventional cigarettes among adolescents include both individual level characteristics (e.g., emotional

regulation and self-esteem), and external influences such as group environment (e.g., parental supervision and support, smoking by family or peers), and organizational/community environment (e.g., exposure to tobacco advertising) [[12], [13], [14]]

This study seeks to address gaps in e-cigarette research in several ways. First, most research has focused on adolescents and conventional cigarettes, not yet e-cigarette use. Second, studies have focused on older adolescents (9th-12th grade students). While the proportion of middle school students who have tried e-cigarettes is smaller than that of high school students, use among younger adolescents is substantial and rising. Identifying factors that may put students at risk for early initiation of e-cigarettes can inform development and implementation of primary and secondary prevention interventions [[3], [10]].

The objectives of this study are to: (1) document prevalence of e-cigarette use and characteristics of young users (i.e., middle school students), including reasons for use; and (2) identify psychosocial and behavioral factors that predict susceptibility and uptake in grade 8 among non-users in grade 7. With a basis in the social-ecological model, we will assess whether individual, group, and organizational level characteristics measured at grade 7 can predict e-cigarette use at grade 8 (community and population level factors will be addressed in the discussion) (see Figure 1). We hypothesize that students who experience greater emotional and behavioral problems and stress, who utilize fewer coping strategies, and who experience less family support and school connectedness in grade 7, will be more likely to consider or initiate use of e-cigarettes in grade 8.

Methods

Study Design

This study is a secondary analysis of data from the Health for Achievement study conducted by Yale School of Public Health's Community Alliance for Research and Engagement, in collaboration with the New Haven Public Schools and the Rudd Center for Food Policy and Obesity [15]. From a total of 27 schools in New Haven, Connecticut, 12 kindergarten through grade 8 schools were randomly selected to participate and all agreed. All procedures were approved by the Yale University Human Subjects Committee and the Board of Education. Parental consent and child assent were collected from all participants in English or Spanish prior to study initiation.

Study Population

Data were collected annually through student surveys, the school district administrative database, and physical measurements ([15]). All students in grade 7 completed surveys in Fall 2013, and the same students then completed surveys in Fall 2014 (as 8th graders). Eighty-nine percent of all eligible students participated. Surveys were administered on desktop computers through SurveyMonkey; research staff read questions and response options aloud while students entered their responses into the survey. Physical measurements (height and weight) were collected by research assistants using the WHO Expanded STEPS protocol. Student demographic data, standards-based test scores and absenteeism were collected from the school district administrative database. To protect student privacy, data were linked with school-assigned identification numbers.

Students were included if they completed surveys in both grade 7 and grade 8 (N=490). Because the focus of this study is on e-cigarette uptake, six students who used e-cigarettes in grade 7 were excluded. Students included in these analyses (N=484), and students excluded (n=225), did not meaningfully differ on most demographic characteristics (race/ethnicity, gender, or food insecurity status) (see Table A-1). Fewer students identifying with a race/ethnicity other than non-Hispanic white, non-Hispanic black, or Hispanic were included in the study, though the actual numerical difference was minimal (n=4). Similarly, students were slightly older, but the average age difference was minimal (0.1 years).

Primary Measures

Primary Outcome Variable

E-cigarette use. Students were asked if they had ever heard of an e-cigarette (Yes/No). Students who answered *Yes* were asked a series of questions: ever used an e-cigarette (Yes/No); what they like about them (e.g., flavors, healthier, looks cool); and, if they think they might try an e-cigarette in the future (Yes/No). Students were classified as susceptible/ 'considering e-cigarette use' if they responded *Yes* to *Do you think you might try an e-cigarette in the future?* and 'used e-cigarettes' if they responded *Yes* to *Have you ever used an e-cigarette?*.

Primary Independent Variables

Emotional and Behavioral Problems. Two subscales of the Strengths and Difficulties Questionnaire were completed by students in grade 7: emotional problems and hyperactivity/inattention [16]. There were five items for each subscale asking about various symptoms (e.g., *you are often unhappy, depressed, or tearful*, and *you are restless, you cannot stay still for long*). To each item, students could respond *Not true*, *Somewhat true*, or *Certainly true*. Responses to items in each subscale were summed to create scale scores ranging from 0-10, with higher scores indicating higher levels of emotional or behavioral problems [17].

Perceived Stress Scale. A shortened version of Cohen and colleagues' validated perceived stress scale (1983) was used [18]. Four items asked about stress in the past month (e.g*., how often have you felt that you were unable to control the important things in your life*). Items were scored on a five-point Likert scale with responses ranging from *Never* to *Very often*. Responses were summed across items to create scale scores ranging from 4-20, with higher scores indicating higher levels of perceived stress.

Shift-and-persist. "Shift-and-persist" refers to having the ability to shift (accept and adapt) to stressors through thinking about stressors in a different light, and being able to persist through finding meaning and optimism in life [19]. The ability to use shift-and-persist strategies was measured using a shortened version of the shift-and-persist measures used by Chen and colleagues [19]. Three "shift" items taken from the Responses to Stress Questionnaire [20] asked about the ability to accept and adapt to stressors (e.g., *I think about the things I can learn from a situation*) [19]. Two "persist" items from the Resilience Inventory [21] and the Purpose in Life Scale [22] asked about the ability to persist through finding meaning and optimism in life (e.g*., I think that things will get better in the future*) [19]. Items were scored on a four-point Likert scale, with responses ranging from *Not at all* to *A lot* [23]. Responses were

summed across items to create scale scores ranging from 5-20, with higher scores indicating use of more shift-and-persist strategies [23].

Family Support. The family support variable was derived from seven items asking about parental/guardian supervision and support (e.g., *how often do your parents or guardians check on whether you've completed your homework*, or *spend time with you doing things you both like to do, such as talking, watching a movie, cooking, or riding bikes*). Items were scored on a four-point Likert scale, with responses ranging from *Never* to *Often*. Responses were summed across all items to create a total score ranging from 7-28, with higher scores indicating greater family support.

School Connectedness. Resnick and colleagues' six-item school connectedness scale was used [24]. Items asked about feelings of closeness with others at school and satisfaction with the school environment (e.g., *The teachers at this school treat students fairly and I feel close to people at this school)*. Items were scored on a five-point Likert scale with responses ranging from *Strongly disagree* to *Strongly agree*. Items were summed to create a total score ranging from 6-30, with higher scores indicating greater school connectedness [25].

Food Insecurity. Food insecurity status was measured using three items adapted from the USDA Child Food Security Module [26]. These items include: during the last 12 months, *I felt worried that our food at home would run out before we could get more*, *I ate less than I wanted to because there wasn't enough food at home*, and *I was hungry, but didn't eat because there wasn't enough food at home*. Items were scored on a three-point Likert scale, *Often*, *Sometimes*, or *Never true*. Items were reverse scored and summed to create a total score ranging from 0-6. Students with a score of 1 or greater were classified as "Food Insecure."

Data Analysis

Descriptive statistics were calculated to assess the prevalence of e-cigarette susceptibility and use among students at grade 7 and grade 8. Scale scores for independent variables were computed for students missing a response to no more than one item in a scale (missing values were calculated using mean imputation). Bivariate associations between mean scale scores for each independent variable at grade 7 and never used or considering e-cigarette use, considering e-cigarette use, and used e-cigarettes at grade 8 were explored; Wilcoxon rank-sum tests were used to assess differences between groups. Logistic regression was used to assess multivariate associations between independent variables (emotional symptoms, hyperactivity/inattention, perceived stress, shift-and-persist strategies, family support, and perceived school connectedness at grade 7) and 'considering e-cigarette use' at grade 8, controlling for demographic variables and 'considering e-cigarette use' at grade 7. Backward elimination was also

conducted (independent variables with p>0.1 were removed one at a time, beginning with the variable with the highest p-value). Similar logistic regression analyses were repeated assessing 'used e-cigarettes at grade 8' as the dependent variable. As it is likely that students within schools are correlated due to the school-based sampling approach, logistic regression analyses were conducted using generalized estimating equations (GEE) with an exchangeable correlation matrix, to account for school clustering. GEE models have been shown to be effective in previous research for modeling non-normal correlated data [7].

To assess the robustness of our analyses, models were validated by calculating the areas under the receiver-operating characteristic (ROC) curves (graphed using 1-specificity on the x-axis and sensitivity on the y-axis), and comparing results to the average area under the ROC curves after 10-fold cross-validation. To assess the goodness-of-fit of our models, QIC statistics, defined as the Quasilikelihood under the Independence model Criterion statistic, were compared. QIC is similar to the AIC (Akaike's Information Criterion) statistic used to compare models created with likelihood-based methods [27]. All analyses were performed using SAS 9.4 (SAS Institute, Cary, NC).

Results

Demographic and Descriptive Statistics

This study includes an ethnically diverse sample of students, composed primarily of Non-Hispanic Black (34.1%) and Hispanic (47.3%) students (Table 1). At least a quarter of students came from self-reported food insecure households (32.1% at grade 7 and 25.7% at grade 8) (Table 1). On average, students reported greater emotional/behavioral difficulties, greater hyperactivity/inattention, and higher perceived stress levels in grade 8 compared to in grade 7 (p<0.05) (Table 1). On average, students also reported use of fewer shift and persist strategies and lower perceived school connectedness in grade 8 compared to in grade 7 (p<0.05). This suggests that as these students aged, they reported, on average, higher emotional/behavioral difficulties and perceived stress levels, lower use of shift and persist strategies, and lower perceived school connectedness levels (Table 1).

Description of E-cigarette use

The majority of students reported hearing of an e-cigarette in both grade 7 (57.8%) and grade 8 (70.8 %), with a significant increase in the proportion of students hearing of e-cigarettes by grade 8 (p<0.001). In grade 7, only 1.2% (n=6) of students reported using e-cigarettes. There was a seven-fold increase by grade 8, with 8.4% (n=41) of students reporting using e-cigarettes (Figure 2).

When e-cigarette users were asked what they like about e-cigarettes, at grade 7, 50% of students reported "looks cool" and "healthier than a regular cigarette" and 33.3% reported "flavors" as a reason for liking e-cigarettes. In contrast, at grade 8, 29.3% of users reported "looks cool" as a reason for liking e-cigarettes, while the majority (68.3%) reported "flavors. This suggests flavors are enticing to students in both grades and are increasingly important.

In grade 8, the percentage of students reporting e-cigarette use surpassed the percentage reporting conventional cigarette use. In grade 7, 4.9% (n=24) of students reported ever trying cigarettes, while only 1.2% (n=6) of students reported ever using e-cigarettes. In grade 8, 7.8% (n=38) of students reported ever trying cigarettes, while 8.4% (n=41) of students reported ever using e-cigarettes. Additionally, in grade 7, 50% (n=3) of students who reported ever using e-cigarettes also reported trying cigarettes, and in grade 8, 26.8% (n=11) of students who reported ever using e-cigarettes also reported trying cigarettes.

Bivariate Analyses

Students who never considered using or used e-cigarettes at grade 8 reported significantly lower levels of hyperactivity symptoms (p<0.05) and lower stress levels (p<0.01), and reported significantly greater levels of school connectedness at grade 7 (p<0.01), compared to students who considered using or used e-cigarettes at grade 8 (Table 2).

On average, perceived stress levels reported in grade 7 were higher among students who went on to consider e-cigarette use in grade 8 (p<0.01), compared to students who did not consider e-cigarette use in grade 8 (Table 2). On average, perceived school connectedness reported in grade 7 was significantly lower (p<0.05) among students who went on to use e-cigarettes in grade 8, compared to students who did not use e-cigarettes (Table 2).

Logistic Regression Analyses

Predictors of E-cigarette Susceptibility. Predictors of considering e-cigarette use at grade 8 were assessed using logistic regression (Table 3). The model adjusted for all predictor variables suggested that perceived stress levels at grade 7 were significantly associated (p<0.01) with susceptibility to e-cigarette use in grade 8. After further adjusting for race/ethnicity, gender, age, food insecurity, and considering e-cigarette use at grade 7, the effect of perceived stress levels was only marginally attenuated, and remained significant (adjusted odds ratio [AOR], 1.21; 95% CI, 1.07-1.36). In this fully adjusted model, shift-and-persist strategies emerged as a marginally significant predictor of considering e-cigarette use (p<0.06). Considering e-cigarette use at grade 7 also significantly predicted considering e-cigarette use at grade 8

(AOR, 8.05; 95% CI, 3.2-20.2). The fully adjusted model suggests that for every one-point increase in perceived stress scale score at grade 7, there is a 21% increase in the odds of considering e-cigarette use at grade 8 (95% CI: 1.07-1.36) . For every one-point increase in shift-and-persist score, there is a 10% marginally significant decrease in the odds of considering e-cigarette use at grade 8 (95% CI: 0.81-1.00).

Pearson correlations between all independent variables included in the fully adjusted model for both students who considered e-cigarette use in grade 8 and those who did not were not higher than 0.6 and 0.5, respectively (and the majority were much smaller). Variance Inflation Factor (VIF) values were small, and all under 10. This suggests multicollinearity is unlikely to be a problem in the multivariate model.

Predictors of E-cigarette Uptake. Predictors of using e-cigarettes at grade 8 were also assessed using logistic regression (Table 3). The model adjusted for all predictor variables suggested that perceived school connectedness at grade 7 was a marginally significant predictor ($p<0.06$) of e-cigarette use at grade 8 (AOR, 0.93; 95% CI, 0.87-0.98). After further adjusting for race/ethnicity, gender, age, food insecurity and considering e-cigarette use at grade 7, school connectedness emerged as a significant predictor ($p<0.05$) of e-cigarette use in grade 8, and the effect size remained the same. Considering e-cigarette use at grade 7 also significantly predicted using e-cigarettes at grade 8 (AOR, 3.7; 95% CI, 1.5-9.4). The fully adjusted model suggests that for every one-point increase in school connectedness score at grade 7, there is a 7% statistically significant decrease in the odds of using e-cigarettes at grade 8 (95% CI, 0.87-0.98).

Pearson correlations between all independent variables included in the fully adjusted model for students who used e-cigarettes at grade 8 and those who did not were not higher than 0.6 and 0.4, respectively (and the majority were much smaller). VIF values were small, and all under 10. This again suggests multicollinearity is unlikely to be a problem in the multivariate model.

Model Validation. The model with 'considering e-cigarette use' as the outcome variable has a QIC statistic of 205.17, and adequate discrimination with an area under the ROC curve of 0.740 (area=1 suggests perfect discrimination, while area=0.5 suggests discrimination is no better than chance) [28]. However, after conducting 10-fold cross-validation, the area under the ROC curve (calculated using the average predictive values from all 10 validation models) decreased to 0.615, which may suggest overfitting. The model resulting from backward elimination that included only marginally significant or significant predictors of considering use (perceived stress and shift and persist) and control variables results in a higher QIC statistic of 208.5 (a smaller statistic suggests a better fitting model), and smaller

area under the ROC curve of 0.710. That being said, with this model there is less attenuation of the area under the ROC curve after 10-fold cross-validation (0.625).

The model with 'used e-cigarettes' as the outcome variable has a QIC statistic of 272.63 and adequate discrimination with an area under the ROC curve of 0.684 [28]. However, after conducting 10-fold cross-validation, the area under the ROC curve is 0.575, suggesting inadequate discrimination and potential overfitting. The model resulting from backward elimination which included only significant predictors of using e-cigarettes (school connectedness) and control variables results in an improved QIC statistic of 266.59, but slightly smaller area under the ROC curve of 0.669. However, once again, with this model there is less attenuation of the area under the ROC curve after 10-fold cross-validation (0.595).

Overall, validation results suggest that the 'considering e-cigarette use' model, with a greater area under the ROC curve, may fit these data better than the 'used e-cigarettes' model. In both models, there was attenuation of the area under the ROC curve after 10-fold cross validation. This may suggest overfitting, as the degree of attenuation after 10-fold cross-validation was smaller using reduced models constructed through backward elimination.

Discussion

Using a cohort of middle school students in an urban setting, this study assessed prevalence and predictors of early e-cigarette susceptibility and initiation. In this sample, there was a seven-fold increase in prevalence of e-cigarette use among middle school students within only one year (from grade 7 to grade 8). Additionally, only 26.8% (n=11) of students who had used e-cigarettes in grade 8 had ever tried conventional cigarettes.

Our study found that students who never used or considered using e-cigarettes at grade 8, reported significantly lower levels of hyperactivity symptoms and stress, and higher levels of school connectedness at grade 7, compared to students who considered using e-cigarettes or used e-cigarettes at grade 8. Results from multivariate regression models suggest that perceived stress significantly predicts e-cigarette susceptibility ($p<0.01$), and shift and persist strategies marginally predict e-cigarette susceptibility ($p<0.06$), after controlling for sociodemographic characteristics. School connectedness significantly predicts e-cigarette uptake ($p<0.05$), after controlling for sociodemographic characteristics. E-cigarette susceptibility at grade 7 significantly predicts both e-cigarette susceptibility and uptake at grade 8 ($p<0.01$).

These findings support previous research on adolescents that has found that stress and cognitive appraisal strategies are significantly associated with conventional cigarette smoking [[29], [30]]. Among a sample of New York City adolescents served by a university-based clinic, perceived stress and negative life events were highest among cigarette smokers, lower among experimenters, and lowest among those who had never smoked [30]. Perceived stress, negative life events, greater use of negative coping methods (such as anger), and lower use of positive coping methods (such as cognitive coping strategies) were significantly associated with conventional cigarette smoking [30]. Our findings also support previous research findings of an inverse association between perceived levels of school connectedness and adolescent cigarette smoking [31].

In contrast, our findings do not support previous research that has found that emotional/behavioral problems and depressive symptoms are predictors of adolescent conventional cigarette use [[17], [32], [33]]. These null findings could be due to a lack of true association between these symptoms and e-cigarette use, or differences between our study and previous research. Giannakopoulos et al. (2010) explored associations between SDQ scales and adolescent smoking and found that conduct problems, which we did not examine, had the largest association with smoking [17]. We also did not look at items from scales designed to screen for depression in children and adolescents, such as the Center for Epidemiological Studies Depression Scale for Children [34]. Additionally, many previous studies have examined associations between emotional/behavioral problems and conventional cigarette use among adolescents of a wider age range (e.g., 12-18 years) [17]. While Goodwin et al. (2004) [35] found that anxiety disorders were significantly associated with nicotine dependence at ages 16-18 and ages 18-21, a study assessing predictors of substance use disorders among younger students (grades 7-9) did not find that anxiety disorders and depression were significant predictors of substance use disorders [36]. Further research is necessary to elucidate any predictive association between emotional/behavioral problems and e-cigarette use among adolescents.

Limitations and Strengths

This study was limited by the small number of students who were considering e-cigarette use or used e-cigarettes in grade 8. This small sample size created limitations in power and generalizability. In terms of power, the sample size resulted in potential attenuation of statistical significance in both bivariate and multivariate analyses, and increased variability surrounding point estimates, despite differences in raw scores of predictor variables. Furthermore, while cross-validation suggests evidence of model overfitting, backward elimination could reduce accuracy of the models in other populations, potentially removing

important predictors of e-cigarette susceptibility and uptake which were not identified in our study due to limited power. In addition, the study sample was composed primarily of low-income, non-Hispanic Black and Hispanic students, so results may not be generalizable to all adolescent populations within the United States.

Another limitation was being unable to control for all factors potentially associated with e-cigarette use. We could not control for socioeconomic status, as information about household income, or mother's education (a frequently used proxy for socioeconomic status) was not available. Instead, food insecurity status (based on self-reported responses to questions about availability of food in the past 12 months) was included in our models, which may not accurately reflect true food insecurity status, or differences across socioeconomic groups. We could not control for school fixed effects in our models either, as some schools did not have any students who were using e-cigarettes or considering e-cigarette use. We also did not have information on factors such as e-cigarette use by family members or peers, which previous research has found to be positively associated with adolescent e-cigarette use [37].

Finally, there was room for improvement in measures used to predict e-cigarette susceptibility and uptake. The Strengths and Difficulties Questionnaire typically includes five scales (emotional problems, conduct problems, hyperactivity/inattention, peer relationship problems, and prosocial behavior), however, we were only able to assess the predictive strength of the two scales included in the grade 7 survey (emotional problems and hyperactivity/inattention). Therefore, our analysis may not have fully captured the variation in emotional or behavioral difficulties present in our sample. Additionally, scale scores for students missing only one item in a scale were calculated using mean imputation for the missing value, which could have reduced variability and attenuated effect sizes.

That said, a key strength of this analysis was its longitudinal design, and the ability to assess predictors of e-cigarette uptake, as opposed to associations with use. While this analysis cannot prove causality, the fact that certain psychosocial predictors were found to precede e-cigarette consideration or uptake, suggests directionality exists. To our knowledge, this is one of the first studies assessing predictors of e-cigarette use in a population consisting solely of middle school-aged students. Future analyses could focus on assessing not only predictors of uptake, but also predictors of greater frequency and intensity of use. Additionally, there is a need for longitudinal analyses to assess factors in early adolescence which may predict use in later adolescence or early adulthood.

Implications for Policy and Practice

E-cigarette uptake is also likely influenced by community and population level characteristics (Figure 1). While federal legislation places age, flavoring, and advertising restrictions on conventional cigarettes, similar federal legislation does not exist for ENDS devices and products. [1]. State age restrictions on the sale of ENDS products to minors began in 2010, and currently sales of ENDS to minors are prohibited under the age of 18 in at least 48 states and the District of Columbia [38]. Though limited research exists on the effects of these recent restrictions, there is some evidence that these restrictions may actually increase conventional cigarette use among adolescents [1].

The American Academy of Pediatrics recommends that pediatricians screen for and provide prevention counseling for ENDS use concurrently with tobacco use, and refer ENDS users to cessation counseling or FDA-approved tobacco cessation products [39]. Additionally, their recommendations for policy change include: banning the sale to and use of ENDS for youth under the age of 21 (including internet sales), banning all ENDS flavors, banning advertising of ENDS that can be seen by youth, and protecting youth from secondhand and thirdhand aerosol exposure through banning ENDS use in public spaces [39].

Our findings suggest that individual level psychosocial and behavioral characteristics may be important predictors of e-cigarette susceptibility, while organizational level characteristics such as school connectedness may be important predictors of e-cigarette uptake. Therefore, interventions targeting stress management at the individual level, and school environment at the organizational level, may aid in curbing e-cigarette use. According to the Centers for Disease Control and Prevention, factors that can increase school connectedness include: adult support, belonging to a positive peer group, commitment to education, and a positive school environment [40]. The results of this study suggest that schools themselves may play a role in influencing e-cigarette uptake, which may be useful to school administrators and other stakeholders in advocating for changes and interventions to improve school connectedness.

According to a policy statement issued by the American Academy of Pediatrics, "Protecting children from tobacco products is one of the most important things that a society can do to protect children's health" [41]. As suggested by the American Academy of Pediatrics and the results of the present study, the prevalence of ENDS is increasing among adolescents, so it is important that further research study the health effects of ENDS use, and evaluate the outcomes of initiatives designed for ENDS prevention in terms of all nicotine product use [39].

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Tables

Table 1. Summary Statistics at grade 7 and grade 8, N=484 students[a]

	Grade 7 % (N) or Mean ± SD	Grade 8 % (N) or Mean ± SD[b]
Demographics		
Race/Ethnicity		
White	16.7 (81)	16.7 (81)
Non-Hispanic Black	34.1 (165)	34.1 (165)
Hispanic	47.3 (229)	47.3 (229)
Other	1.9 (9)	1.9 (9)
Age	12.8 ± 0.53	13.74 ± 0.53***
Gender		
Female	53.3 (258)	53.3 (258)
Male	46.7 (226)	46.7 (226)
Food Insecurity		
Yes	32.1 (152)	25.7 (121)***
No	67.9 (322)	74.3 (349)
Scales		
Strengths & Difficulties		
Emotional Scale	2.9 ± 2.4	3.2 ± 2.5
Hyperactivity Scale	3.3 ± 2.0	3.6 ± 2.1**
Perceived Stress	9.9 ± 2.7	10.5 ± 2.9**
Shift and Persist	15.1 ± 3.4	12.8 ± 3.0**
Family Support	20.7 ± 4.1	20.6 ± 4.1
School Connectedness	23.6 ± 4.4	23.0 ± 4.6**

a. Numbers may not sum to 484 due to missing data, and percentages may not sum to 100 due to rounding.
b. P-value for t-test/Wilcoxon signed-rank test (continuous variables) or χ2 test/fisher's exact test (categorical variables). Statistically significant, **p<0.05, ***p<0.01.

Table 2. Mean psychosocial and behavioral scale scores in grade 7 by e-cigarette use in grade 8, N=484 students

Scale	Mean (SD) (n=484)	Never Considered or Used E-cigarettes Mean (SD)		P-value[b]	Considered E-cigarette Use Mean (SD)[a]		P-value[b]	Used E-cigarettes Mean (SD)[a]		P-value[b]
		Yes (n=406)	No (n=68)		Yes (n=30)	No (n=444)		Yes (n=38)	No (n=435)	
Strengths & Difficulties										
Emotional	2.9 (2.4)	2.9 (2.3)	3.1 (2.6)	0.630	2.8 (2.6)	2.9 (2.4)	0.524	3.4 (2.6)	2.9 (2.3)	0.220
Hyperactivity/inattention	3.3 (2.0)	3.2 (2.0)	3.8 (1.9)	0.036**	3.8 (1.9)	3.2 (2.0)	0.155	3.7 (1.8)	3.2 (2.0)	0.070*
Perceived stress	9.9 (2.7)	9.7 (2.7)	10.9 (2.5)	0.001***	11.2 (2.8)	9.8 (2.7)	0.004***	10.7 (2.3)	9.8 (2.7)	0.055*
Shift and Persist	15.1 (3.4)	15.2 (3.4)	14.4 (3.5)	0.064*	14.0 (3.3)	15.2 (3.4)	0.060*	14.7 (3.7)	15.2 (3.4)	0.503
Family Support	20.7 (4.1)	20.8 (4.0)	19.8 (4.3)	0.067*	19.7 (4.2)	20.8 (4.1)	0.207	19.8 (4.4)	20.8 (4.0)	0.194
School Connectedness	23.6 (4.4)	23.8 (4.3)	22.3 (4.0)	0.002***	22.7 (3.5)	23.6 (4.3)	0.069*	22.0 (4.4)	23.7 (4.3)	0.0216**

a. Numbers may not sum to 484 due to students with missing data for more than one item in a scale.
b. P-value for Wilcoxon rank-sum test. Marginally significant, *p<0.1. Statistically significant, **p<0.05, ***p<0.01.

Table 3. Multivariate associations between psychosocial and behavioral scales at grade 7 and e-cigarette susceptibility and uptake at grade 8.

Scales	Considered E-cigarette Use		Used E-cigarettes	
	Adjusted[a] (n=467)[c]	**Fully Adjusted[b] (n=460)[c]**	**Adjusted[a] (n=465)[c]**	**Fully Adjusted[b] (n=458)[c]**
	OR (CI)	**OR (CI)**	**OR (CI)**	**OR (CI)**
Strengths & Difficulties				
Emotional	0.85 (0.72, 1.01)*	0.85 (0.66, 1.11)	1.01 (0.84, 1.21)	1.01 (0.82, 1.25)
Hyperactivity	1.11 (0.95, 1.28)	1.07 (0.93, 1.24)	1.03 (0.84, 1.27)	1.01 (0.80, 1.28)
Perceived Stress	1.24 (1.09, 1.40)***	1.21 (1.07, 1.36)***	1.09 (0.94, 1.26)	1.06 (0.92, 1.22)
Shift and Persist	0.96 (0.89, 1.03)	0.90 (0.81, 1.00)*	1.02 (0.98, 1.06)	1.01 (0.96, 1.06)
Family Support	0.98 (0.93, 1.03)	1.00 (0.94, 1.06)	0.97 (0.90, 1.05)	0.98 (0.90, 1.08)
School Connectedness	1.00 (0.94, 1.06)	1.00 (0.92, 1.09)	0.93 (0.86, 1.00)*	0.93 (0.87, 0.98)**

All models conducted using generalized estimating equations (GEE) to account for school clustering.
OR= odds ratio, CI= confidence interval.

a. Models adjusted for all predictor variables (emotional symptoms, hyperactivity symptoms, perceived stress, shift-and-persist, family support, and school connectedness).
b. Models adjusted for race/ethnicity, gender, age, food insecurity, and considering e-cigarette use at grade 7, and all predictor variables. Marginally significant, *p<0.1. Statistically significant, **p<0.05, ***p<0.01.
c. Sample size for models not equal to 484 due to students with missing data for more than one item in a scale, and missing data for considering e-cigarette use (n=5) or used e-cigarettes (n=7) at grade 8. Sample was not restricted to non-missing values for outcome variables prior to modeling due to students with a missing value for considering e-cigarette use, and a valid value for used e-cigarettes, and vice versa.

Figures

Figure 1. Social-ecological model to describe adolescent use of ENDS products
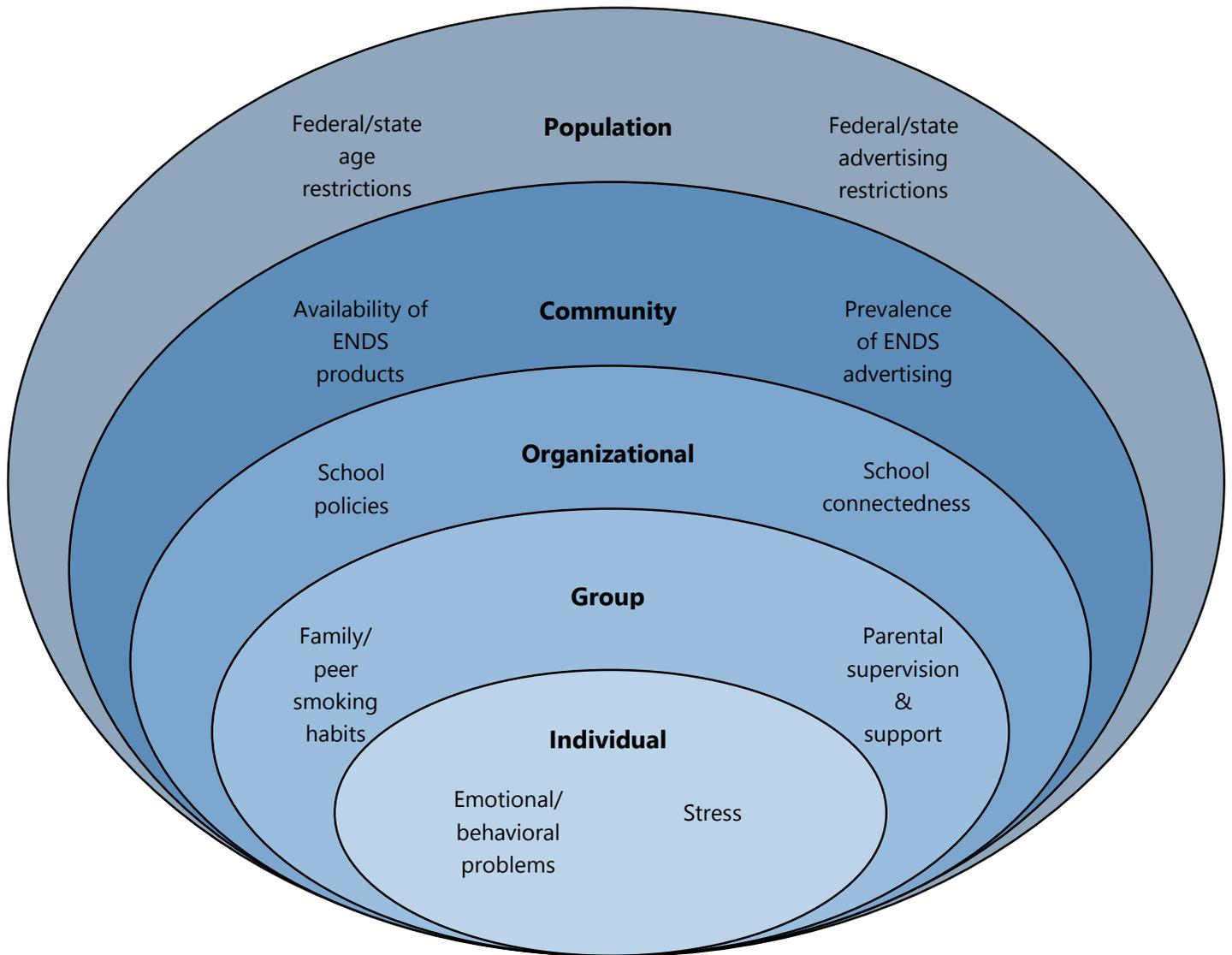
Figure 2. Distribution of e-cigarette susceptibility and use among grade 7 (a) and grade 8 (b) students, N=490.

a.
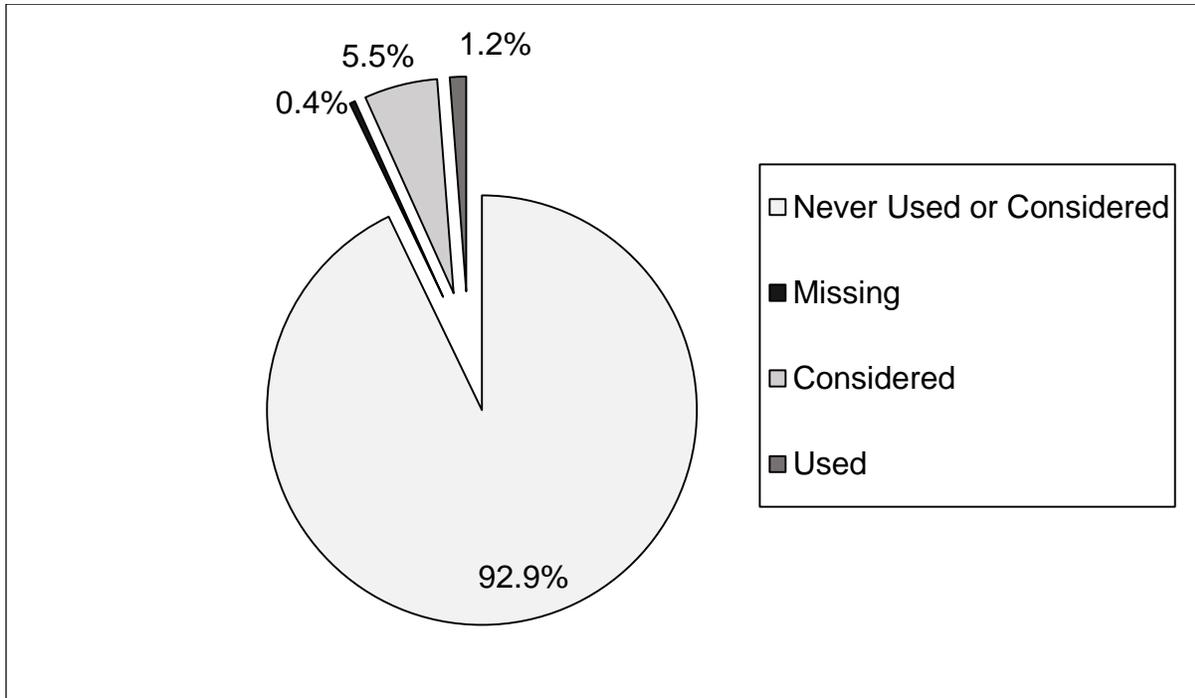
b.
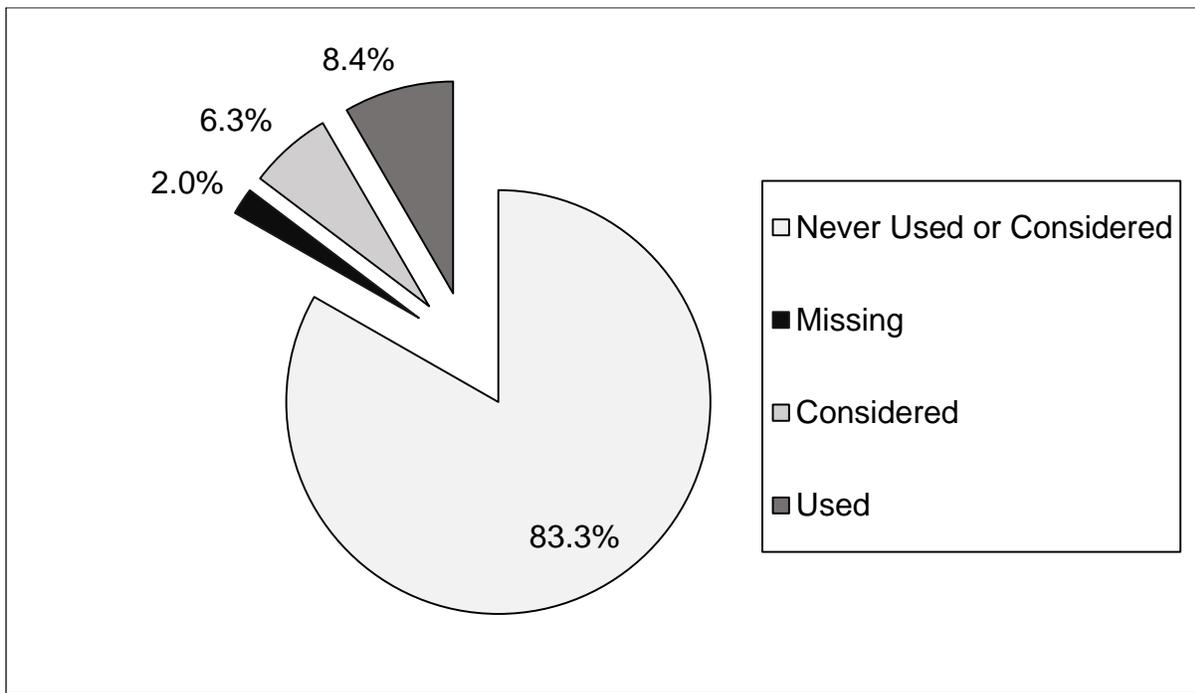
Figure 3. Mean scale scores in grade 7 for students who never used or considered (n=406), considered using (n=30), or used e-cigarettes (n=38) in grade 8. Statistically significant, **p<0.05, ***p<0.01. Error bars represent 95% confidence intervals for the mean scale scores.
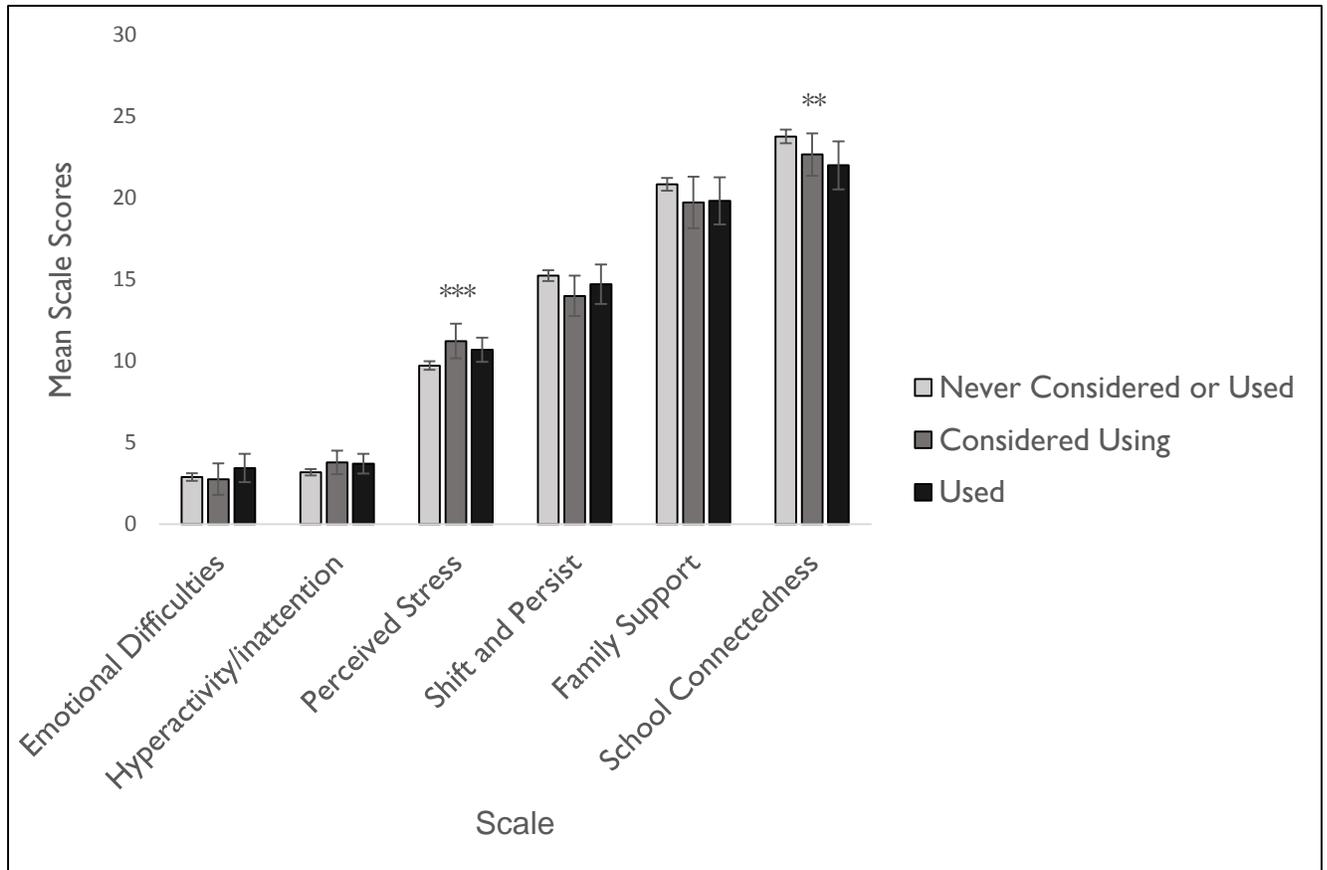
Table A.1. Demographic characteristics and mean scale scores for students included and excluded in present study

Characteristic	Students with both grade 7 and grade 8 data who have not used e-cigarettes in grade 7 N=484 % (N) or Mean ± SD*	Students with data from grade 7 or grade 8 (but not both), or students have used e-cigarettes in grade 7 N=225 % (N) or mean ± SD*	P-value[+]
Race/ethnicity			
Non-Hispanic white	16.7 (81)	13.5 (28)	0.289
Non-Hispanic black	34.1 (165)	30.9 (64)	0.417
Hispanic	47.3 (229)	49.3 (102)	0.636
Other	1.9 (9)	6.3 (13)	0.002
Missing	0	18	
Age of 7th graders	12.8 ± 0.5	12.9 ± 0.6	0.005
Missing	0	59	
Female	53.3 (258)	55.6 (115)	0.587
Missing	0	18	
Food Insecure	32.1 (152)	33.8 (45)	0.701
Missing	10	92	
Strengths and Difficulties			
Emotional Score	2.9 ± 2.4	2.8± 2.3	0.495
Missing	3	90	
Hyperactivity Score	3.3 ± 2.0	3.8± 1.9	0.007
Missing	4	91	
Perceived Stress	9.9 ± 2.7	10.0 ± 2.7	0.491
Missing	8	91	
Shift and Persist	15.1± 3.4	14.3 ± 3.5	0.015
Missing	3	91	
Family Support	20.7 ± 4.1	20.2 ± 4.6	0.266
Missing	6	91	
School Connectedness	23.5 ± 4.35	22.6 ± 4.9	0.078
Missing	4	90	

*Numbers may not sum to 484 or 225 due to missing data, and percentages may not sum to 100%, due to rounding

[+]P-value for t-test/Wilcoxon Rank Sum test (continuous variables) or χ2 test/fisher's exact test (categorical variables).