Sources of acquisition and frequency of e-cigarette use among adolescents in the United States

Adeniran Esther
East Tennessee State University College of Public and Allied Health
Awasthi Manul
East Tennessee State University College of Public and Allied Health
Oke Adekunle
East Tennessee State University College of Public and Allied Health
Brooks Billy
East Tennessee State University College of Public and Allied Health
Ahuja Manik
East Tennessee State University College of Public and Allied Health
Antwan Jones
George Washington University School of Public Health and Health Services: The George Washington University Milken Institute of Public Health
Weierbach W Florence
East Tennessee State University College of Nursing
Fletcher R. Adkins
East Tennessee State University College of Arts and Sciences
Hadii M. Mamudu (mamudu@etsu.edu)
East Tennessee State University College of Public and Allied Health

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Abstract

Purpose: Despite strategies prohibiting e-cigarettes use and purchase, the literature suggests continued use and access by adolescents. Guided by the Socio-Ecological Model, we examined sources and types of e-cigarettes along with the associated frequency of use among U.S school-going adolescents.

Methods: We used the 2019 National Youth Tobacco Survey comprising U.S middle and high schoolers (n=19,018). Multinomial logistic regression was conducted to evaluate associations between sources and types of e-cigarettes, and the frequency of use while controlling for covariates.

Results: The final sample was 3,537 with 76.9% high schoolers, 51.6% males, and 59.7% prefilled pods/cartridges users (JUUL). Past-month e-cigarette use was 60.8% for 1-10 days, 14.3% for 11-20 days, and 24.9% for 21-30 days. Sources adolescents obtained e-cigarettes included retail stores (20.1%), vape shops (15.2%), internet (7.1%), social networks (74.0%), and unknown sources (5.9%). Compared to 1-10 days, 21-30 days e-cigarette use was higher among participants who obtained e-cigarettes from retail stores [OR= 3.03; 95% CI= 3.009-3.046; P<0.001], vape shops [OR= 3.42; 95% CI= 3.393-3.439; P<0.001], and the internet [OR= 1.85; 95% CI= 1.839-1.872; P<0.001] than from other sources, but lower when obtained from social networks [OR= 0.63; 95% CI= 0.628-0.636; P<0.001]. Using e-cigarettes like JUUL was associated with higher odds of 21-30 days [OR= 1.11; 95% CI= 1.106-1.120; P<0.001] use than refillable e-cigarette tank.

Conclusion: Factors within the organizational and community levels, including types (JUUL) and sources of e-cigarette (retail stores, vape shops, and internet), were associated with a higher frequency of past-month use.

Introduction

Electronic cigarettes (e-cigarettes) are the most commonly used tobacco product among middle and high schoolers in the United States (U.S.) [1]. In 2019, the prevalence of past 30 days e-cigarette use was 10.5% and 27.5% among middle and high schoolers, respectively [2]. Increased e-cigarette use among this population occurs amidst evidence that adolescents' developing brains are more susceptible to adverse effects of nicotine, including increased risk-taking behaviors and nicotine dependence [3]. Associations exist between early exposure to e-cigarette use and subsequent use of conventional tobacco products (CTPs), as well as misuse of other substances [4, 5]. Concerns around carcinogen production [6], and the renormalization of CTPs, threatens to undermine decades of tobacco control efforts, particularly due to weak regulatory regimes across the U.S [3, 7–9].

Since its arrival in the U.S., e-cigarette use has spread across various demographic, socioeconomic, and geographic subgroups [9, 10]. However, the association between sources of acquisition and frequency of e-cigarette use among adolescents has not been fully explored. Evidence indicates that perception of e-cigarettes as safer than CTPs, parents/peers e-cigarette use, and marketing efforts targeting adolescents increase the prevalence of e-cigarettes use among middle and high schoolers [11, 12] States have enacted different policies that prohibit youth <18 years (currently <21 years federally) from accessing tobacco products, including e-cigarettes [13, 14]. However, the literature suggests continued access by adolescents; besides, current moderate users are more likely to obtain e-cigarettes from retailers than from friends or family [15–17]. The literature also suggests the need to explore types of e-cigarettes used by adolescents that could influence frequency of use [17]. High sales of e-cigarettes like JUUL, have prompted other e-cigarettes products to adopt JUUL's innovative nicotine salt delivery design [18]. Thus, investigating sources and types of e-cigarettes along with the associated frequency of use among U.S adolescents may aid policy/programmatic initiatives.

This study examined various sources of e-cigarettes and associated frequency of use among middle and high schoolers in the U.S. Additionally, we examined the types of e-cigarettes used and associated frequency of use in this study population. Informed by the literature [2,17], it is hypothesized that access to e-cigarettes from Vape Shops, Internet, Retail Outlets, and Social Networks will be positively associated with increased frequency of use. Additional hypothesis was that most types of e-cigarettes will be positively associated with frequency of use, with JUUL being the leading type. This is because JUUL currently dominates the e-cigarette market place and its innovative design is being adopted by other e-cigarettes types [18]. This study was guided by the Socio-Ecological Model (SEM) of health promotion. SEM describes the interactive and multi-leveled attributes of individuals and environments that underlie health behaviors/outcomes like e-cigarette use and is recommended to guide public health practice and inform policies/intervention strategies [19, 20].This study focused on the frequency of e-cigarette use and its association with factors at the intrapersonal/individual, interpersonal, organizational, and community levels. To the best of our knowledge, no study to date has examined how sources of e-cigarettes is associated with frequency of use among middle and high schoolers or utilized the SEM to explicate such relationships. Importantly, the current study is backed by an existing literature that highlights the need to continually monitor where adolescents obtain e-cigarettes [15]. Identifying adolescents e-cigarettes sources can help inform interventions to limit e-cigarette access, frequency of use, and dependence.

Methods

Data source

This study utilized the 2019 National Youth Tobacco Survey (NYTS) data collected from February 15, 2019, to May 24, 2019. NYTS is a cross-sectional self-administered survey on tobacco-related indicators among U.S. middle (grades 6-8) and high (grades 9-12) schoolers. Stratified three-stage cluster sampling produced a nationally representative sample of public/private school students. Details about sampling, survey administration, addressing non-responses, and response rates is published elsewhere [21]. A total of 19,018 students completed the 2019 survey, with an overall response rate, including school-and-student level participation of 66.3%. This study's inclusion criteria were past 30 days e-cigarette use and having complete data for variables used in the analyses. No study variable had missing values >5%, thus no issue with missingness [22]. After excluding missing/invalid data, and those who responded "0 days" e-cigarette use, the final analytic sample for this study was 3,537. East Tennessee State University's Institutional Review Board considered this research as exempt.

Measures

The use of tobacco products, including e-cigarette, is impacted by several factors occurring within the various SEM levels; therefore, the National Cancer Institute (NCI) recommended the SEM for examining tobacco use behavior [20]. Table 1 shows the variables from the literature [16–18, 23, 24], that were assessed in this study and the level within the SEM. Although, the NYTS is self-reported by individuals, examining the variables through the lens of the SEM ensures that interventions are targeted and tailored at the appropriate SEM level. Details of study variables are provided in eTable 1 in the supplement.

Table 1
Selected Study Variables in National Youth Tobacco Survey (NYTS) and level within the Socioecological Model (SEM) of Health Promotion

Level of SEM	NYTS Variable
Intrapersonal/Individual	Demographics (sex, grade level, and race/ethnicity)
Interpersonal	Social networks (family, peers, and others except family/peers)
Organization	E-cigarette advertisements or promotions and types of e-cigarettes
Community	Vape shops, retail outlets (Gas station/convenience store, grocery store, drug store, a mall or shopping center kiosk/stand), and internet
Policy	---
*Note: S*ome of these selected variables could potentially occur at more than one level within the SEM; however, the most appropriate level was selected for this study. NYTS: National Youth Tobacco Survey; SEM: Socio-Ecological Model — indicates that policy level of the SEM was not addressed in this study	

Outcome

Frequency of e-cigarette use

The outcome variable was current use of e-cigarettes. Respondents were asked: “During the past 30 days on how many days did you use e-cigarettes?” Responses ranged from 0 to 30 days. Based on existing literature [25], responses were categorized as 1-10 days (referent), 11-20 days, and 21-30 days for this study. Thus, all participants whose response was 0 were excluded.

Independent variables

Sources of e-cigarettes

The main independent variable for this study is “sources of e-cigarettes”, which could occur within the SEM's interpersonal and/or community levels (Table 1). This was assessed with the question, “During the past 30 days, where did you get or buy the e-cigarettes that you have used? (Select one or more).” Responses included: 1) Gas station/convenience store, 2) Grocery store, 3) Drugstore, 4) Mall/shopping center kiosk/stand, 5) Internet, 6) Vape shop or other store that only sells e-cigarettes, 7) Some other place not listed here, 8) Family member, 9) Friend, and 10) Some other person (not including a family member/friend). Based on a 2016 study by Kong et al.,[15] responses 1-4 were categorized as “retail stores”, 5 as “internet”, 6 as “vape shops” and placed at the community level of the SEM, responses 8-10 were categorized as “social networks” and determined as the interpersonal level of the SEM; response 7 was termed “unknown sources”.

Types of e-cigarettes

“Types of e-cigarettes” are products by the industry; therefore, it was determined as an organizational level factor within the SEM (Table 1). Respondents were asked: “Which best describes the type of e-cigarette you have used in the past 30 days?” Responses included: 1) Disposable e-cigarette, 2) E-cigarette that uses prefilled pods/cartridges (JUUL), 3) E-cigarette with a tank that you refill with liquids, 4) Mod system (customized by the user with their own combination of batteries and atomizers), 5) I do not know the type. Response 5 was excluded as emphasis was on the known types of e-cigarettes.

Covariates

The covariates included factors assessed at the intrapersonal/Individual-level (demographic characteristics) and organizational (e-cigarettes advertisements or promotions) levels of the SEM (Table 1). Demographic characteristics included sex, grade level, and race/ethnicity. Sex was assessed with the question “What is your sex?” with responses “Male” or “Female”, race/ethnicity was assessed with “What race (s) do you consider yourself to be?” and responses recoded as Hispanic, Non-Hispanic Black, Non-Hispanic White, and other races. Grade level was ascertained as “What grade are you in?” and responses categorized as middle (grades 6-8) and high school (grades 9-12). Exposure to e-cigarette advertisements or promotions was assessed with the question “How often do you see advertisements or promotions for e-cigarettes?” for the following: “television/streaming services/go to the movies (TSM)”, “internet”, “newspapers or magazines”, and “convenience store, supermarket or gas station”. In this study, “convenience store, supermarket or gas station” were termed “retail outlets”.

Statistical analysis

Statistical analysis was performed using SAS version 9.4 (SAS Institute, Cary, NC, USA). Descriptive statistics, bivariate analysis, and models were weighted to account for the complex survey design. Bivariate analysis included chi-square test (Table 3) and simple multinomial logistic regressions (eTable 2 in the supplement), with frequency of e-cigarettes used as the outcome. Independent variables significantly associated with the outcome in individual regression models were included in the adjusted regression model at P=0.20 [26]. As informed by the literature [27, 28], we conducted multicollinearity test, and all correlations met the cut-off of <0.70, suggesting no collinearity issues for all sources of e-cigarettes included in the final model. Multinomial logistic regression was performed to evaluate associations between “sources of acquisition of e-cigarettes” and “types of e-cigarettes”, and the frequency of e-cigarette use while controlling for sex, grade level, race/ethnicity, and exposure to e-cigarette advertisements or promotions. Likelihood ratio test ascertained model fit (P<0.001). A two-tailed P≤ 0.05 was considered statistically significant in the final model.

Results

Participant characteristics

Table 2 shows results of the descriptive statistics. Of the total participants (n=3,537), 51.6% were males, 76.9% were high school students, and 60.4% were non-Hispanic Whites. Participants who said ‘yes’ to obtaining e-cigarettes from the various sources were as follows: retail stores (20.1%), vape shops (15.2%), internet (7.1%), social networks (74.0%), and unknown sources (5.9%). Past-month frequency of e-cigarette use was 60.8% for 1-10 days, 14.3% for 11-20 days, and 24.9% for 21-30 days. Also, 59.7% used e-cigarette with prefilled pods/cartridges (JUUL). Table 3 shows the frequency distribution of e-cigarette use in relation to all principal independent variables and the covariates in this study. All variables were significantly associated with the outcome.

Table 2
Sociodemographic characteristics of the population (N=3537)

Variables	N (%)
Sex	
Male	1863 (51.6)
Female	1659 (48.4)
Grade level	
Middle school	874 (23.1)
High school	2646 (76.9)
Race/ethnicity	
Hispanic	982 (23.0)
Non-Hispanic Black	287 (8.3)
Non-Hispanic White	1882 (60.4)
Other races	341 (8.3)
Sources of acquisition of e-cigarettes	
Retail stores	
No	2886 (79.9)
Yes	651 (20.1)
Vape shops	
No	3016 (84.8)
Yes	521 (15.2)
Internet	
No	3307 (92.9)
Yes	230 (7.1)
Social networks	
No	875 (26.0)
Yes	2662 (74.0)
Unknown sources	
No	3334 (94.1)
Yes	203 (5.9)
Frequency of electronic cigarette used in the past-month	
1-10 days	2169 (60.8)
11-20 days	501 (14.3)

Variables	N (%)
21-30 days	865 (24.9)
Types of e-cigarettes used	
E-cigarette with a tank that you refill with liquids	890 (26.5)
Disposable e-cigarette	102 (2.9)
E-cigarette that uses prefilled pods or cartridges (e.g., JUUL)	1873 (59.7)
A mod system	336 (10.9)
Exposure to e-cigarette advertisements or promotions on TSM	
No	1439 (42.5)
Yes	1950 (57.5)
Exposure to e-cigarettes advertisements or promotions on the internet	
No	741 (21.8)
Yes	2684 (78.2)
Exposure to e-cigarettes advertisements or promotions from newspapers or magazines	
No	1916 (56.0)
Yes	1486 (44.0)
Exposure to e-cigarettes advertisements or promotions from retail outlets	
No	521 (15.8)
Yes	2878 (84.2)

Proportions were weighted to account for the complex sampling design.

Unweighted participant counts are reported.

Counts for each variable may not add up to 3,537 due to missing/incomplete data

Weighted % are reported.

N=3,537 (final analytic sample)

TSM: television/streaming services/go to the movies

Table 3
Frequency distribution of e-cigarette use according to the predictor variables (N=3537)

Variables	Frequency of e-cigarette use			
	1-10 days N= 2169 (%)	11-20 days N= 501 (%)	21-30 days n = 865 (%)	P-value
Sex				
Male	1037 (55.2)	298 (16.2)	526 (28.5)	**< 0.001**
Female	1119 (66.5)	203 (12.3)	337 (21.2)	
Grade level				
Middle school	645 (72.5)	108 (12.6)	119 (14.8)	**< 0.001**
High school	1515 (57.2)	390 (14.8)	741 (28.0)	
Race/ethnicity				
Hispanic	670 (70.6)	141 (13.2)	170 (16.2)	**< 0.001**
Non-Hispanic Black	218 (78.9)	37 (10.8)	32 (10.3)	
Non-Hispanic White	1037 (54.1)	270 (15.1)	575 (30.8)	
Other races	214 (62.2)	50 (15.9)	77 (21.9)	
Sources of acquisition of e-cigarettes				
Retail stores				
No	1917 (66.6)	384 (13.7)	583 (19.7)	**< 0.001**
Yes	252 (37.6)	117 (16.7)	282 (45.7)	
Vape shops				
No	1994 (65.3)	423 (14.5)	597 (20.2)	**< 0.001**
Yes	175 (35.3)	78 (13.3)	268 (51.4)	
Internet				
No	2081 (62.4)	463 (14.2)	761 (23.4)	**< 0.001**

Variables	Frequency of e-cigarette use			
	1-10 days N= 2169 (%)	11-20 days N= 501 (%)	21-30 days n = 865 (%)	P-value
Yes	88 (39.7)	38 (15.6)	104 (44.7)	
Social networks				
No	355 (41.5)	141 (15.5)	379 (43.0)	**< 0.001**
Yes	1814 (67.5)	360 (13.9)	486 (18.6)	
Unknown sources				
No	2075 (61.5)	471 (14.2)	786 (24.2)	**< 0.001**
Yes	94 (48.5)	30 (15.3)	79 (36.1)	
Types of e-cigarettes used				
E-cigarette with a tank that you refill with liquids	534 (61.3)	126 (13.6)	230 (25.1)	**< 0.001**
Disposable e-cigarette	57 (57.2)	18 (15.0)	27 (27.8)	
E-cigarette that uses prefilled pods or cartridges (e.g., JUUL)	1092 (57.6)	290 (15.7)	491 (26.7)	
A mod system	192 (53.6)	47 (15.7)	97 (30.7)	
Exposure to e-cigarette advertisements or promotions on TSM				
No	849 (59.3)	206 (13.9)	382 (26.8)	**< 0.001**
Yes	1227 (61.8)	274 (14.3)	449 (23.9)	
Exposure to e-cigarettes advertisements or promotions on the internet				
No	431 (57.8)	98 (12.5)	211(29.7)	**< 0.001**
Yes	1673 (61.8)	384 (14.5)	626 (23.7)	
Exposure to e-cigarettes advertisements or promotions from newspapers or magazines				
No	1150 (59.8)	274 (13.4)	491 (26.8)	**< 0.001**
Yes	939 (62.3)	203 (14.7)	343 (23.0)	

Variables	Frequency of e-cigarette use			
	1-10 days N= 2169 (%)	11-20 days N= 501 (%)	21-30 days n = 865 (%)	P-value
Exposure to e-cigarettes advertisements or promotions from retail outlets				
No	334 (64.6)	69 (11.6)	117 (23.8)	**< 0.001**
Yes	1751 (60.0)	409 (14.5)	717 (25.5)	

Proportions were weighted to account for the complex sampling design.

Unweighted participant counts are reported.

Weighted and row percentages were reported.

N=3,537 (final analytic sample)

Counts for each variable may not add up to 3,537 due to missing/incomplete data

TSM: television/streaming services/go to the movies

Multivariable associations

Table 4 shows results of multivariable data analysis. Compared to 1-10 days, the odds of the frequency of 11-20 days [OR= 1.92; 95% CI= 1.901-1.931; P< 0.001] and 21-30 days [OR= 3.03; 95% CI= 3.009-3.046; P< 0.001] e-cigarette use were higher among adolescents who obtained e-cigarette from retail stores than those who obtained from other sources. Adolescents who got their e-cigarettes from vape shops had higher odds of 11-20 days [OR= 1.40; 95% CI= 1.391-1.416; P< 0.001] and 21-30 days [OR= 3.42; 95% CI= 3.393-3.439; P< 0.001] frequency of use compared to those who obtained e-cigarettes from other sources. Likewise, adolescents who obtained their e-cigarettes from the internet had higher odds of 11-20 days [OR= 1.29; 95% CI= 1.277-1.306; P< 0.001] and 21-30 days [OR= 1.85; 95% CI= 1.839-1.872; P< 0.001] frequency of use than those who obtained e-cigarettes from other sources. Conversely, getting e-cigarettes from social networks was associated with lower odds of 11-20 days [OR= 0.83; 95% CI= 0.827-0.840; P< 0.001] and 21-30 days [OR= 0.63; 95% CI= 0.628-0.636; P< 0.001] e-cigarette use than from other sources. Obtaining e-cigarettes from unknown sources was associated with higher odds of 11-20 days [OR= 1.45; 95% CI= 1.434-1.468; P< 0.001] and 21-30 days [OR= 1.31; 95% CI= 1.296-1.323; P< 0.001] e-cigarette use than those who obtained from other sources.

Table 4
Multinomial logistic regression showing the relationship between independent variables and frequency of e-cigarette use

Variables	Adjusted model					
	11-20 days vs. 1-10 days			21 to 30 days vs. 1-10 days		
	OR	95% CI	P-value	OR	95% CI	P-value
Sex (Male vs Female)	1.59	1.581-1.599	**< 0.001**	1.36	1.353-1.367	**< 0.001**
Grade level (High school vs Middle school)	1.39	1.378-1.397	**< 0.001**	1.63	1.623-1.644	**< 0.001**
Race/ethnicity (REF = Non-Hispanic White)						
Hispanic	0.70	0.693-0.703	**<0.001**	0.42	0.414-0.419	**<0.001**
Non-Hispanic Black	0.55	0.540-0.552	**< 0.001**	0.18	0.174-0.178	**<0.001**
Other races	0.87	0.865-0.883	**< 0.001**	0.66	0.655-0.668	**< 0.001**
Sources of acquisition of e-cigarettes						
Retail stores (Yes vs No)	1.92	1.901-1.931	**< 0.001**	3.03	3.009-3.046	**< 0.001**
Vape shops (Yes vs No)	1.40	1.391-1.416	**< 0.001**	3.42	3.393-3.439	**< 0.001**
Internet (Yes vs No)	1.29	1.277-1.306	**< 0.001**	1.85	1.839-1.872	**< 0.001**
Social networks (Yes vs No)	0.83	0.827-0.840	**< 0.001**	0.63	0.628-0.636	**<0.001**
Unknown sources (Yes vs No)	1.45	1.434-1.468	**< 0.001**	1.31	1.296-1.323	**< 0.001**
Types of e-cigarettes used (REF= E-cigarette with a tank that you refill with liquids)						
Disposable e-cigarette	1.05	1.032-1.069	**< 0.001**	0.77	0.759-0.783	**< 0.001**
E-cigarette that uses pre-filled pods or cartridges (e.g., JUUL)	1.14	1.137-1.152	**< 0.001**	1.11	1.106-1.120	**< 0.001**
A mod system	1.19	1.174-1.198	**< 0.001**	1.05	1.045-1.063	**< 0.001**
Exposure to e-cigarette advertisements or promotions on TSM (Yes vs No)	0.97	0.967-0.979	**<0.001**	1.02	1.009-1.020	**< 0.001**

Variables	Adjusted model					
	11-20 days vs. 1-10 days			21 to 30 days vs. 1-10 days		
	OR	95% CI	P-value	OR	95% CI	P-value
Exposure to e-cigarettes advertisements or promotions on the internet (Yes vs No)	1.01	0.996-1.013	0.263	0.64	0.631-0.639	**< 0.001**
Exposure to e-cigarettes advertisements or promotions from newspapers or magazines (Yes vs No)	1.01	1.007-1.019	**< 0.001**	0.87	0.865-0.874	**< 0.001**
Exposure to e-cigarettes advertisements or promotions from retail outlets (Yes vs No)	1.39	1.378-1.404	**< 0.001**	1.31	1.303-1.323	**< 0.001**

Models were weighted to account for the complex sampling design.

REF= Reference; CI, Confidence interval; OR, Odds ratio; P ≤ 0.05

TSM: television/streaming services/go to the movies

With respect to types of e-cigarettes, adolescents who used e-cigarettes with pre-filled pods or cartridges (JUUL) had significantly higher odds of 11-20 days [OR= 1.14; 95% CI= 1.137-1.152; P< 0.001] and 21-30 days [OR= 1.11; 95% CI= 1.106-1.120; P< 0.001] frequency of use than refillable e-cigarette tank users (referent). Similarly, adolescents who used mod system had greater odds of 11-20 days [OR= 1.19; 95% CI= 1.174-1.198; P< 0.001] and 21-30 days [OR= 1.05; 95% CI= 1.045-1.063; P< 0.001] frequency of use. Further, disposable e-cigarette users had slightly higher odds of 11-20 days [OR= 1.05; 95% CI= 1.032-1.069; P< 0.001] and lower odds of 21-30 days [OR= 0.77; 95% CI= 0.759-0.783; P< 0.001] e-cigarettes use.

The results for factors examined within the individual level of the SEM (Table 1 and 4) show that compared to 1-10 days past-month e-cigarette use, the odds of the frequency of 11-20 days [OR= 1.59; 95% CI= 1.581-1.599; P< 0.001] and 21-30 days [OR= 1.36; 95% CI= 1.353-1.367; P< 0.001] use was significantly greater among males than females. Also, the odds of the frequency of 11-20 days [OR=1.39; 95% CI= 1.378-1.397; P< 0.001] and 21-30 days e-cigarette use [OR=1.63; 95% CI= 1.623-1.644; P< 0.001] were significantly higher among high schoolers than middle schoolers. Compared to Non-Hispanic White, adolescents who identified as Hispanic had lower odds of 11-20 days [OR= 0.70; 95% CI = 0.693-0.703; P< 0.001] and 21-30 days [OR= 0.42; 95% CI = 0.414-0.419; P< 0.001] e-cigarette use. Similarly, those who identified as Non-Hispanic Blacks had lower odds of 11-20 days [OR= 0.55; 95% CI = 0.540-0.552; P< 0.001] and 21-30 days [OR= 0.18; 95% CI = 0.174-0.178; P< 0.001] e-cigarette use. Likewise, adolescents who identified as other races had lower odds of 11-20 days [OR= 0.87; 95% CI = 0.865-0.883; P< 0.001] and 21-30 days [OR= 0.66; 95% CI = 0.655-0.668; P< 0.001] e-cigarette use.

At the organizational level of the SEM, we found that adolescents who were exposed to e-cigarette advertisements or promotions on TSM had significantly lower odds of 11-20 days [OR= 0.97; 95% CI= 0.967-0.979; P< 0.001] and slightly higher odds of 21-30 days [OR= 1.02; 95% CI= 1.009-1.020; P< 0.001] frequency of use than those not exposed to such advertisements or promotions. Conversely, those who were exposed to advertisements or promotions on the internet had lower odds of 21-30 days [OR= 0.64; 95% CI= 0.631-0.639; P< 0.001] frequency of use than those not exposed. Adolescents exposed to e-cigarettes advertisements or promotions in newspapers or magazines had slightly higher odds of 11-20 days [OR= 1.01; 95% CI= 1.007-1.019; P< 0.001], but lower odds of 21-30 days [OR= 0.87; 95% CI= 0.865-0.874; P< 0.001] frequency of use than adolescents not exposed to them. Those exposed to e-cigarettes advertisements or promotions in retail outlets had significantly higher odds of 11-20 days

[OR= 1.39; 95% CI= 1.378-1.404; P< 0.001] and 21-30 days [OR= 1.31; 95% CI= 1.303-1.323; P< 0.001] frequency of e-cigarette use than their counterparts.

Discussion

Although there are few studies on the sources of e-cigarettes acquisition [15, 16, 29], this is the first study to utilize national data comprising of both middle and high schoolers in the U.S. Guided by the SEM, as recommended by the NCI [20], we examined access to e-cigarettes, and association with frequencies of use. We found that the rate of 21-30 days frequency of e-cigarettes use was 24.9% i.e., 1 in 4 respondents were heavy users. This indicates that a significant number of U.S. youth are exposed to nicotine, which affects brain development [30].

Further, our findings show that e-cigarettes were obtained from interpersonal (family, peers, and other social networks) and mostly from community (retail stores, vape shops, and the internet) sources. This illuminates that youths continue to have access to e-cigarettes despite policies to restrict access [31]. Notably, acquisition of e-cigarettes from community sources significantly increased the frequency of e-cigarette use, while interpersonal sources (social networks) was associated with a lower frequency of use, confirming prior state-level studies on this issue [15–17, 32]. Consistent with policy statements by the American Public Health Association [33, 34] these results buttress the need to enforce state [35], and federal policies [36], to restrict youth access to e-cigarettes, while targeting community level factors.

Additionally, this study determined e-cigarette types as organizational level factors within the SEM. We found that e-cigarettes with prefilled pods/cartridges (JUUL) were the most frequently used (21-30 days), supporting the evidence that JUUL is the most popular [37, 38], and most frequently used [2, 39], e-cigarette among U.S. adolescents. This may be due to JUUL's variety of flavors, users' belief that it is less harmful, and social influences [18, 40, 41]. Hence, targeting product types for regulation, could mitigate the increasing use of e-cigarettes. Relatedly, policies banning flavors in e-cigarettes by the U.S. Food and Drug Administration [42], are headed in the right direction. Exposure to e-cigarette advertisements or promotions was also examined at the organizational level. Consistent with prior studies [43, 44], exposure to e-cigarette advertisements or promotions in retail outlets was significantly associated with a higher frequency of e-cigarettes use among middle and high schoolers. Since the Master Settlement Agreement [45], the retail environment has fostered youths' exposure to advertisements or promotions, with concomitant ramifications for the product uptake [46]. Similarly, research suggests that youths in the U.S. are highly exposed to e-cigarettes in retail outlets [30]. Thus, it is crucial to enact policies that limit or prevent youth exposure to e-cigarette advertisements within retail outlets.

Finally, at the intrapersonal/individual level of the SEM, we found that males were more likely to use e-cigarettes for 11-20 and 21-30 days, which is consistent with previous studies [47–49]. These results suggest the need for tailoring different (public) health messages for males and females in middle and high schools in the U.S. Further, our results show that being in high school was associated with a higher frequency of e-cigarette use, which confirms findings in prior studies [1, 47, 50] Indeed, reports from the 2020 NYTS reflect that 38.9% of high-school and 20.0% of middle-school students used e-cigarettes for ≥20 days in the past-month [39]. This suggests that high school is a critical phase in the trajectory of e-cigarette use and warrants further research. Lastly, Hispanics, non-Hispanic Blacks, and other races used e-cigarettes less frequently than non-Hispanic Whites. These results are consistent with previous research that found that the prevalence of frequent e-cigarette use was greater among non-Hispanic Whites [47, 51] Hence, more research on racial disparities in e-cigarette use among U.S. youths is needed.

This study has few limitations. Firstly, access to tobacco products, including e-cigarettes, is illegal in some states for people aged <18 years [14]; therefore, this may have affected the self-reporting of sources of e-cigarettes with the potential of underestimating results. Secondly, data were collected only from middle and high schoolers who attended public/private schools. Hence, our results may not be generalizable to all adolescents in the U.S [12]. Lastly, since this was a cross-sectional study, we cannot establish causation or temporal relationship.

Conclusions

This study found that among middle and high schoolers, a higher frequency of past-month e-cigarette use was significantly associated with JUUL use and obtaining e-cigarettes from retail stores, vape shops, and the internet. This suggests that interventions to address frequency of e-cigarette use should target factors within the organizational and community levels of the SEM. At the intrapersonal/individual level, being male, being a high schooler, and being non-Hispanic White was significantly associated with increased frequency of e-cigarette use. While these results suggest the need for targeted interventions, it also stresses the need for further research into why these subgroups are predisposed to higher e-cigarette use frequency. Ultimately, a more comprehensive approach to addressing the sources of youth acquisition of e-cigarette is needed to limit access to e-cigarette products in the U.S.

Declarations

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Author Contributions: Adeniran conceptualized and designed the study, acquired data, carried out statistical analysis and interpretation of data, drafted the initial manuscript, and reviewed and revised the manuscript for important intellectual content. Awasthi and Oke conceptualized and designed the study, carried out interpretation of data, drafted the initial manuscript, and reviewed and revised the manuscript for important intellectual content. Dr. Brooks had full access to the data in the study, supervised analysis, contributed to the interpretation of data, and reviewed and revised the manuscript for important intellectual content. Dr. Ahuja contributed to statistical analysis, interpreted data, and revised and reviewed the manuscript for important intellectual content. Dr. Antwan, Dr. Weierbach, and Dr. Fletcher, interpreted data, and revised and reviewed the manuscript for important intellectual content. Dr. Mamudu conceptualized and designed the study, drafted the initial manuscript, reviewed and revised the manuscript for important intellectual content, and supervised all aspects of the research. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Data Availability: The dataset analyzed during the current study are available in the Centers for Disease Control and Prevention website [https://www.cdc.gov/tobacco/data_statistics/surveys/nyts/index.htm]

Ethics approval: This is an observational study. The East Tennessee State University Institutional Review Board has confirmed that no ethical approval is required.

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